Mines and Minerals Branch Report of Activities 1990

D.R. MacDonald,
Editor

Report 91-1

Nova Scotia

Department of Mines and Energy

Honourable C.W. MacNeil, M.D.
Minister Responsible for Mines and Energy

John Mullally
Deputy Minister

Halifax, Nova Scotia
1991

92-01673/

Editor: D. R. MacDonald

Word Processing: B. L. MacDonald

Cartography: J. Campbell
W. Burt
P. Belliveau
J. DeWolfe
G. MacDonald
C. Phillips
P. Fraser
R. MacPherson
E. Limpert
J. Webster

Photography: R. Morrison
C. Murphy

Publications of the Nova Scotia Department of Mines and Energy are available through the departmental libraries at:

1701 Hollis Street, 3rd Floor
Halifax, Nova Scotia
B3J 2X1
(902) 424-8633

32 Bridge Avenue
Stellarton, Nova Scotia
B0K 1S0
(902) 752-8429

TABLE OF CONTENTS

Page

ENERGY RESOURCES DIVISION

Petroleum Resources Section Update - *D. J. MacDonald* 1

MINERAL DEVELOPMENT DIVISION

Automation in the Mineral Development Division - *L. Crust* 5

Metallic Mineral Occurrences Database Activities - *G. DeMont* 7

Integrated Land-Use Project - *D. B. Hopper* 9

Drill Core Libraries - *J. D. Langille* 13

Mineral Inventory - *N. A. Lyttle* 15

Mineral Exploration Monitoring Activities - *P. D. McCulloch* 17

Core Library Activities - *B. Palmer* 25

The Thermal Evolution of the Maritimes Basin: Evidence from Apatite Fission Tract Analysis - *R. J. Ryan, A. M. Grist and M. Zentilli* 27

Core Library Database - *D. Weir* 33

MINERAL RESOURCES DIVISION

Carboniferous Basins Project Activities, 1990 - *R. C. Boehner* 35

Seismic Interpretation, Potential Overthrust Geology and Mineral Deposits in the Kennetcook Basin, Nova Scotia - *R. C. Boehner* 37

Variation in the Mafic Mineral Content of the Scrag Lake Pluton, South Mountain Batholith: Evidence for a Zoned Pluton - *R. J. Horne, M. C. Corey, L. J. Ham and M. A. MacDonald* 49

A Mineralogical and Fluid Inclusion Study of the West Gore Sb-Au Deposit, Meguma Terrane, Southern Nova Scotia - *D. J. Kontak and P. K. Smith* 61

EXTERNAL ABSTRACTS AND CONFERENCE PRESENTATIONS

Seismic Interpretation, Potential Overthrust Geology and Mineral Deposits in the Kennetcook Basin, Nova Scotia - *R. C. Boehner* 75

U-Th-Pb Systmetics of the South Mountain Batholith, Nova Scotia - *A. K. Chatterjee and L. J. Ham* 76

Variations in LIL Elements, HFS Elements and REEs within the Davis Lake Pluton, Southwestern Nova Scotia - *A. K. Chatterjee and R. J. Horne* 77

Contrasting Greisens and Associated Granitoid Rocks of the Davis Lake Pluton: Implications for the Origin of the East Kemptville Tin Deposit, Nova Scotia - *A. K. Chatterjee and M. A. MacDonald* 78

Potential Source Rocks for Gold in Meguma-Hosted Auriferous Vein Deposits, Nova Scotia - *A. K. Chatterjee and P. K. Smith* 79

Characteristics of REE and other Trace Elements in Response to Successive and Superimposed Metasomatism within a Portion of the South Mountain Batholith, Nova Scotia, Canada - *M. C. Corey and A. K. Chatterjee* 80

Seismic Identification of Porosity in Jurassic Carbonate, Offshore Nova Scotia - *P. J. Harvey* 81

Fluorescence Properties of Alginite-Rich Oil Shales from the Stellarton Basin, Canada - *W. Kalkreuth, R. Naylor, K. Pratt and W. Smith* 82

Lithoprobe East Marine Deep Seismic Reflection Data, Bay of Fundy and the Gulf of Maine: Pre-preliminary Interpretation - *C. E. Keen, W. Kay, J. D. Keppie, F. Marillier, B. McLean, G. Pe-Piper, G. S. Stockmal and J. W. F. Waldron* 83

Introduction to Terrane Analysis and the Tectonic Map of Pre-Mesozoic Terranes in Circum-Atlantic Phanerozoic Orogens - *J. D. Keppie and R. D. Dallmeyer* 84

Detrital Zircon Ages from the Late Precambrian Conglomerate, Avalon Composite Terrane, Antigonish Highlands, Nova Scotia - *J. D. Keppie and T. E. Krogh* 88

U-Pb Isotopic Data from Nova Scotia: Clues for Establishing Terrane Linkages - *J. D. Keppie and T. E. Krogh* 89

The East Kemptville Topaz-Muscovite Leucogranite, Nova Scotia: I. Geological Setting and Whole-Rock Geochemistry - *D. J. Kontak* 91

The East Kemptville Topaz-Muscovite Leucogranite, Nova Scotia: II. Mineral Chemistry - *D. J. Kontak* 92

$^{40}Ar/^{39}Ar$ Chronological Study of the Liscomb Complex, Meguma Terrane, Southern Nova Scotia - *D. J. Kontak, A. K. Chatterjee, P. H. Reynolds and K. Taylor* 93

Geochronological Evidence for Multiple Tectonothermal Overprinting Events in the East Kemptville Muscovite-Topaz Leucogranite, Yarmouth County, Nova Scotia, Canada - *D. J. Kontak and R. F. Cormier* 94

Rb/Sr and $^{40}Ar/^{39}Ar$ Geochronological Studies of the Tin-bearing East Kemptville Leucogranite, S. W. Meguma Terrane, Nova Scotia: Evidence for Multiple Episodes of Tectono-Thermal Perturbations - *D. J. Kontak, R. F. Cormier and P. H. Reynolds* 95

A Mineralogical and Fluid Inclusion Study of the West Gore Sb-Au Deposit, Central Meguma Terrane, Nova Scotia: A Possible High-level Analogue for Mesothermal Meguma Group Lode-gold Deposits - *D. J. Kontak and P. K. Smith* 96

Geological and $^{40}Ar/^{39}Ar$ Geochronological Constraints on the Timing of Quartz Vein Formation in Meguma Group Lode-gold Deposits, Nova Scotia - *D. J. Kontak, P. K. Smith, P. Reynolds and K. Taylor* 97

Absolute Dating of Meguma Gold Mineralization in the Eastern Meguma Terrane Using $^{40}Ar/^{39}Ar$ Technique: Chronological Evidence for Convergent Metallotectonic Processes in the Meguma Terrane at ca. 370 Ma - *D. J. Kontak, P. K. Smith, P. H. Reynolds and K. Taylor* 98

SPANS GIS: Modelling our Chemical Environment - *P. J. Rogers* 99

Mineral Exploration Using Catchment Basin Analysis to Integrate Regional Stream Sediment Geochemical and Geological Information in the Cobequid Highlands, Nova Scotia - *P. J. Rogers, G. F. Bonham-Carter and D. J. Ellwood* 101

Metallogenic Domains and their Reflection in Regional Lake Sediment Surveys from the Meguma Zone, Southern Nova Scotia - *P. J. Rogers, A. K. Chatterjee and J. W. Aucott* 102

Baseline Geochemical Mapping Using Lake Sediments - *P. J. Rogers, J. A. C. Fortescue and J. G. Ogden* 103

Geochemical Background: Implications for Environmental Geochemistry in Nova Scotia, Canada - *P. J. Rogers and J. G. Ogden III* 105

Geochemical Background: Implications for the Environment - *P. J. Rogers, J. G. Ogden III and J. A. C. Fortescue* 108

Lithostratigraphic Revision of the Upper Carboniferous to Lower Permian Strata of the Cumberland and Pictou Groups in the Cumberland Basin, Nova Scotia, and Regional Implications for the Maritimes Basin - *R. J. Ryan, R. C. Boehner and J. H. Calder* 110

Geology, Geochemistry, and Exploration Applications for the Permo-Carboniferous Redbed Copper Deposits of the Cumberland Basin, Nova Scotia, Canada - *R. J. Ryan, R. C. Boehner, R. R. Stea and P. J. Rogers* 111

Interpretation of Till Geochemical Data in Nova Scotia, Canada, Using Mapped Till Units, Multi-Element Anomaly Patterns, and the Relationship of Till Clast Geology to Matrix Geochemistry - *R. G. Turner and R. R. Stea* 112

APPENDIX 1

Nova Scotia Department of Mines and Energy Publications Available for Purchase 113

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 1-4

PETROLEUM RESOURCES SECTION UPDATE

D. J. MacDonald

INTRODUCTION

The Petroleum Resources Section is responsible for monitoring and providing a regulatory regime for petroleum activities in both the offshore and onshore regions of Nova Scotia. The section has become involved with the federal government in a joint management regime for the offshore region. In addition, the section has initiated a number of studies and research projects and has made its information and databases available to industry. Oral presentations and poster displays at technical conferences have served to focus attention on Nova Scotia's petroleum potential.

ONSHORE PETROLEUM ACTIVITY

Consultants A.G.R.E.N. completed the drilling of a well, South Noel #1, in the area of Kennetcook, Hants County, in April 1990 (Fig. 1). The 345 m well was drilled as a requirement under the exploration agreement for third year activity. The drilling resulted from a seismic survey conducted in the area in 1986 by the agreement holder. The rights holder has negotiated a second term of three years on the lands with another drilling commitment.

The consortium of New World Ventures, Far Away Resources and Bird Oil, who acquired other lands in the vicinity, have completed the first year of their three year initial term. They have filed reports which provide new information on the petroleum potential of the area. During year two, which commenced 1 November 1990, they are required to undertake a geophysical program, or other such work, which will help to establish a drilling location for their third year commitment. It is hoped that with success by these rights holders, and the interest being expressed by other companies, the onshore region will continue to be of interest.

The Department of Mines and Energy will likely issue another request in 1991 or 1992 for industry to indicate their interests in pursuing petroleum in the onshore. This is done through a process known as a "Call for Proposals" in which industry requests the government to post lands of interest.

Source Rock Study

The long-awaited report on the petroleum source rocks of onshore Nova Scotia is nearing completion. Additional field work in the fall of 1990 produced more samples which will require further laboratory work in an attempt to fill in some blanks in the maps and facilitate the interpretations and conclusions. Several trends have emerged and new interpretations of structural style in the Carboniferous rocks of Cape Breton Island are emerging. The report is in the final stages of preparation and will produce a significant database as well as maps showing maturation profiles which highlight areas of greatest potential. This will provide an excellent base for industry in their continued search for onshore petroleum.

Coal Bed Methane

Staff from the Petroleum Resources Section and from the Coal Section have begun to work together to investigate coal bed methane. There have been a surprising number of inquiries by industry as the value of this resource is being realized. Activity elsewhere, in western Canada and the Unites States, has shown coal bed methane to be one of the energy reserves of the future. Nova Scotia, with its vast coal deposits in numerous sedimentary basins, has undetermined potential to produce coal bed methane. An inventory of the coal deposits in the province has been done, and assessment of the methane potential of these deposits is planned. These efforts will involve long-term, multi-disciplinary research. It is hoped that the outcome of this initiative will be to provide a database to facilitate the efforts of industry.

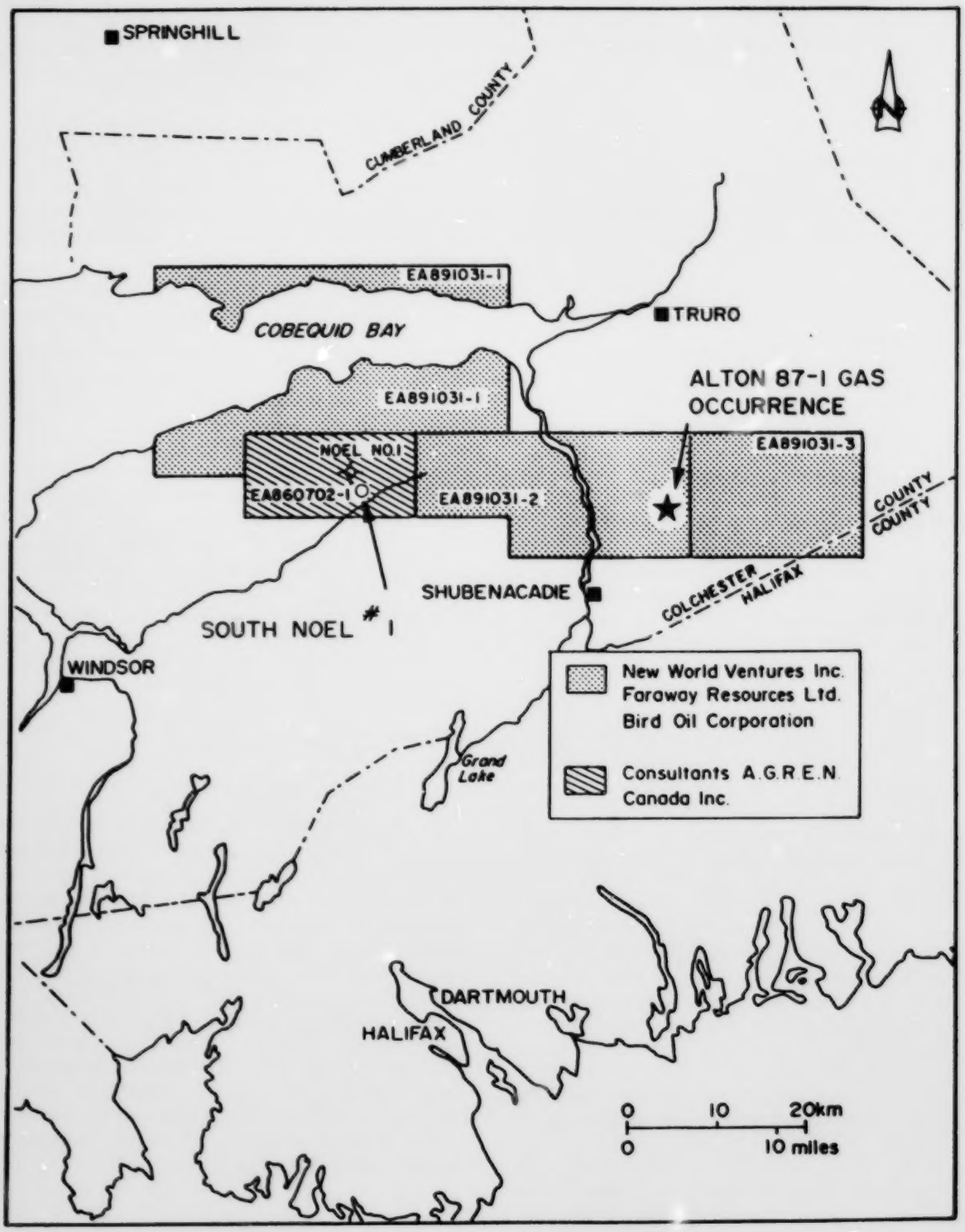

Figure 1. Onshore petroleum exploration agreements and location of the South Noel #1 well.

OFFSHORE ACTIVITY

Industry Activities in the Offshore

Since 1989, several significant events have occurred in Nova Scotia's offshore petroleum sector. The governments of Nova Scotia and Canada have appointed the Canada - Nova Scotia Offshore Petroleum Board, and LASMO and Nova Scotia Resources (Ventures) Limited (NSRL) have been given the go-ahead for the development of the Cohasset - Panuke oil fields (Fig. 2).

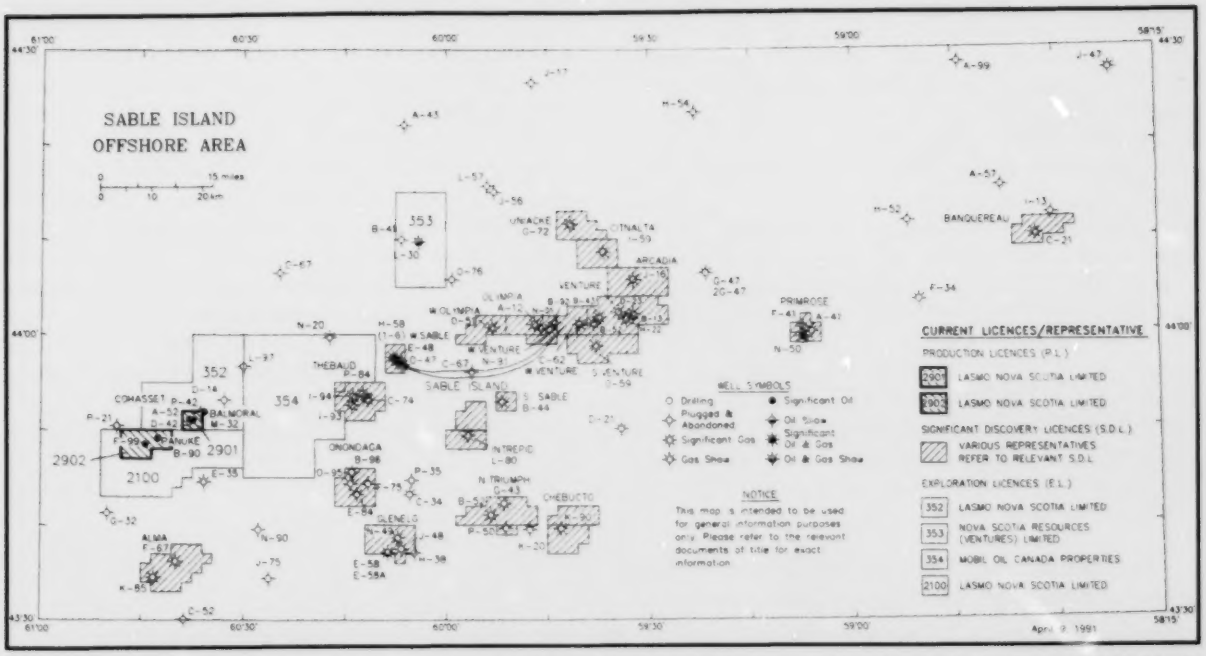
SABLE ISLAND
OFFSHORE AREA
CURRENT LICENCES/REPRESENTATIVE
PRODUCTION LICENCES (P.L.)
2902 LASMO NOVA SCOTIA LIMITED
2903 LASMO NOVA SCOTIA LIMITED
SIGNIFICANT DISCOVERY LICENCES (S.D.L.)
VARIOUS REPRESENTATIVES REFER TO RELEVANT S.D.L.
EXPLORATION LICENCES (E.L.)
352 LASMO NOVA SCOTIA LIMITED
353 NOVA SCOTIA RESOURCES (VENTURES) LIMITED
354 MOBIL OIL CANADA PROPERTIES
2100 LASMO NOVA SCOTIA LIMITED
WELL SYMBOLS
NOTICE
This map is intended to be used for general information purposes only. Please refer to the relevant documents of title for exact information.
April 2, 1991

Figure 2. Exploration licences in the Sable Island offshore area. Note the location of the Cohasset and Panuke oil fields to the west of Sable Island.

In January 1990 the federal and provincial governments appointed a five-member Offshore Petroleum Board. This board, which was established under the Canada - Nova Scotia Offshore Petroleum Resources Accord Implementation Acts, is now responsible for regulating the province's offshore petroleum resources. The board has a small staff of technical experts to advise it. The board will evaluate the resource potential, administer petroleum exploration and production rights, approve offshore exploration, development, and production activities, and be responsible for the approval of benefits and development plans. Certain fundamental decisions are subject to review by the federal and provincial energy ministers. The provincial minister retains the right to provide directives, suspensions, and vetoes on such activities as issuing calls for bids, setting out terms and conditions of exploration licenses, establishing royalties, and approval of Part I of development plans.

In March 1990 the board appointed a commission, which subsequently held public hearings in various areas throughout the province, to consider the environmental and socio-economic impacts of the development of the Cohasset and Panuke offshore oil fields. There were few objections to the development raised at these meetings. The board, having done its own review of the development plan, has since reviewed the commission's report and in September 1990 recommended approval of the project subject to 24 conditions. There has been extensive review by the province of both the development plan and the commission's findings.

The Cohasset - Panuke offshore development is small by global standards, with anticipated production of a total of 35 million barrels over a six year period. It will, however, demonstrate the

viability of production from offshore Nova Scotia and will generate several economic benefits to the province. Direct employment and spin-off benefits to the business sector, plus royalties to the province, will be obvious benefits. As well as providing new sources of oil, this project will establish the credibility of Canada's offshore as a production area. If all goes according to plan, oil will be pumped from a field off the Nova Scotia coast for the first time by 1992.

On the exploration side, LASMO has carried out two seismic programs during the past year on Exploration Licence 352 (Fig. 2). In the fall of 1990 a conventional seismic survey was conducted in the Cohasset area and earlier in 1990 a three-dimensional seismic program was conducted over the Panuke field. Geotechnical and site specific work has also been undertaken over the field areas.

Mobil Oil conducted a seismic program west of Sable Island on Exploration Licence 354 (Fig. 2) in August 1990 which hopefully will lead to the re-commencement of exploration for new natural gas fields on the Scotian Shelf.

Early in 1991 LASMO and NSRL plan to use the Rowan Gorilla III jack-up rig to drill two exploration wells northeast of Cohasset (Exploration Licence 352) on acreage acquired jointly in October 1989.

In August, the Offshore Petroleum Board accepted a bid from LASMO and NSRL, each with a 50% share, for $2.6 million worth of exploration work on Exploration Licence 2100 (Fig. 2) immediately south of the Cohasset and Panuke discoveries. The companies are required to drill a well within three years.

Indications are strong that there is renewed interest in offshore Nova Scotia and indications are that another exploration cycle is about to begin.

Section Activities in the Offshore

The Petroleum Resources Section has been directly involved in royalty aspects of the pending offshore development as these are provincial concerns and are quite separate from the Offshore Petroleum Board's activities. The section has also initiated several research studies in the offshore region, focusing on a prominent, extensive Jurassic carbonate bank (cf. abstract by Harvey, this volume). Identification of hydrocarbon-bearing zones using seismic modelling techniques has generated considerable interest by industry. This is a new initiative and the procedure and results have been presented at several technical conferences attended by international audiences. Poster displays and promotional materials have been created and provided to industry by section staff. Presentation of these materials at conferences and oil shows continues to provide information to the petroleum industry.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 5

AUTOMATION IN THE MINERAL DEVELOPMENT DIVISION[1]

L. Crust

BACKGROUND

The development and use of computer applications within the Mineral Development Division have continued to progress over the past year. Our local area network currently has 14 workstations, including nine workstations within the Mineral Development Division, three in the Mining Engineering Division, one in the Energy Resources Division, and one in the Finance and Administration Division. The Stellarton office has four microcomputers. Major applications for computers remain database management (using Advanced Revelation®), word processing (using WordPerfect®), communications (using Pibterm®), spreadsheet (using Lotus 123®), and business graphics (using Harvard Graphics®).

WORK IN PROGRESS

Work is continuing on development of an automated system of record-keeping for the Registry of Mineral and Petroleum Titles. Databases for storing information on applications, licenses, leases and transfers are now in use, and it is anticipated that soon automated routines on the computer will perform the search of title involved in title registration.

The Library now has an automated system for its card catalogue and inventory of publications. All new acquisitions are entered directly into the computerized system, and acquisition lists and books of Library holdings are generated automatically. A new workstation was installed in the Library recently, allowing the public to perform on-line searches of the Library catalogue as well as of other databases. The Library is also able to access the Novanet catalogue, giving on-line access to listings of materials held by the local universities.

Other databases currently on the system or under development include drillholes, industrial minerals, metallic minerals, maps, production statistics, and various land use databases.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Corporation Agreement on Mineral Development 1990-1992

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 7

METALLIC MINERAL OCCURRENCES DATABASE ACTIVITIES[1]

G. DeMont

In order to improve the quality and reliability of information in the metallic mineral data cards and database, the program of systematic reference researching and checking, coupled with selected field checking, continued over the period January to December 1990. During this period, 50 mineral occurrence data cards were researched and checked. Forty-one of these data cards were revised and updated, nine data cards were eliminated from the dataset and six new metallic mineral occurrences have been documented. Reference checking was completed on N.T.S. map sheets 11K/03, 11N/02, 11D/12 and 21A/16. The Metallic Mineral Occurrence Database contained revised and updated information on 317 occurrences as of 31 December 1990.

Field checking of selected metallic mineral occurrences on Cape Breton Island was undertaken in July and August of 1990, on N.T.S. map sheets 11F/14, 11K/01, 11K/02, 11K/06 and 11K/07. Assessment of the data collected in the field was still in progress as of 31 December 1990. The samples collected had been sent for geochemical analysis, and portions had been slabbed for hand specimen evaluation. Portions of selected specimens had also been sent for thin and polished section preparation. The compiled data on the field-checked occurrences were released as an Open File Report in February 1991.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Corporation Agreement on Mineral Development 1990-1992

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 9-11

INTEGRATED LAND-USE PROJECT[1]

D. B. Hopper

An Integrated Land-Use Program has been established to address and monitor the various land allocation and resource management issues that affect mineral resource management objectives in Nova Scotia. A realization is emerging that environmental and economic planning cannot proceed separately any longer. Resource management and land allocation decisions must be placed within the context of sustainable development objectives, as defined by the World Commission on Environment and Development. 'Sustainable development' is broadly defined as: "Meeting the needs of the present, without compromising the ability of future generations to meet their own needs". In the context of resource management it is a concept that calls for the incorporation of balance, fairness and common ground in our policies and regulations to ensure economic and environmental health. On one hand, economic activity should be congruent with sustainable environmental planning objectives; on the other hand, environmental planning objectives should lead to the implementation of land and resource allocation decisions that are based on comprehensive, integrated sets of socio-economic data.

The Integrated Land-Use Program's central objective is to encourage a full assessment of mineral resource potential in all land and resource management plans in Nova Scotia. The major aim is to direct mineral and energy resources data and other earth science information to the provincial and municipal planning process. This entails providing input to future land use planning, and ensuring that decision-makers in land and resource allocation issues are well informed of the potential for any mineral- and energy-resource activity for any part of Nova Scotia.

There is a growing concern over an increase of conflicting land-use issues surrounding mineral exploration and development, including a gradual reduction of land access due to other resource management and municipal planning pressures. The amount of land available for exploration has a direct bearing on the overall discovery potential for mineral and energy wealth. Issues of land access and conflicting land use converge when municipal plans inadvertently guide community development over or near potential mineral deposits. There is a concern that municipal land-use policies and by-laws do not adequately account for mineral resource potential lying hidden below the surface. The Land-Use Program is attempting to channel this type of information to the provincial and municipal planning community.

A three-phased approach has been defined to carry out the project. Phase one involves gathering information and developing a mineral land-use information base. The products include a series of Mineral Resource Land-Use (MRLU) maps and handbooks. Phase two will incorporate mineral potential mapping of Nova Scotia. Phase three will focus on developing land-use policy recommendations concerning mineral, aggregate and energy resource lands. The groundwork will be laid for the adoption of a provincial land-use policy in accordance with section 7 of the Planning Act.

Mineral Resource Land-Use (MRLU) map sets have been compiled and released as Open File Maps for Halifax County (OFM 88-001 to 88-012); Hants County (OFM 88-017 to 88-022); Cape Breton County (OFM 88-033 to 88-038); Kings County (OFM 88-044 to 88-049); and Lunenburg County (OFM 89-005 to 89-009). Maps in preparation include the Pictou County set. MRLU Handbooks are in preparation for the Province of Nova Scotia, Halifax County and Hants County. This year the program's land use planner started to give

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Cooperation Agreement on Mineral Development 1990-1992

presentations to municipal planners whose areas are covered by Mineral Resource Land-Use mapping. In addition, a paper entitled, "Mineral Resource Management and Land-Use Planning: A Background Study", is in preparation. This paper discusses the results of a survey on mineral-based issues within the context of municipal land-use planning.

MINERAL LAND-USE DATABASE

The development of the mineral land-use database is a continuing effort. Land-use and resource management bibliographic information is being keyed into a networked relational database (Revelation®).

LAND AND RESOURCE PLANNING

In addition to reviewing papers and policy produced on resource management and land use, the program records and monitors changing land use that directly and indirectly affects land access to the mineral industry. Examples include tracking all newly designated ecological reserves, designated water supply watersheds, and reviewing sustainable development policies concerning Nova Scotia's coastal areas, the framework for the Federal Green Plan, and material produced by the Provincial Round Table on Environment and Economy.

Throughout the year the department receives requests for mineral resource information from planners, planning consultants and resource managers. Several information packages with reports and maps have been prepared for specific land management plans and projects. Some examples include utility corridor plans, site location plans for ash disposal, criteria for power plant site location, environmental impact assessments, park plans, and land-use monitoring studies within watersheds.

PROTECTED LANDS MAPPING

In cooperation with the Mining Association of Canada (MAC) the Land Use Program has provided input to MAC's Mining Industry Land Use Strategy (MILUS). MILUS is being developed to compile information and mapping on protected and limited-use lands across Canada, and to establish a measure of available lands for the Canadian exploration and mining industry. The Protected and Limited-Use Lands map, developed in 1985 by the department's land use program, is being used to demonstrate an approach to MILUS digital mapping and archive file construction. The MAC version will use a computer-based spatial information system to store, report and retrieve land-use information for the Canadian mineral industry. An updated version of the department's Protected Lands Map and Handbook of Nova Scotia is in progress. New land categories are being plotted, such as ten-year aquaculture lease/licenses, ecological sites and old growth forests. It is hoped that this information will be made available in digital and non-digital form.

PITS AND QUARRY REHABILITATION STUDY

The final report, entitled *A Study on Pits and Quarries Rehabilitation*, was completed this year by Gardner Pinfold Economists and their Associates. The report stresses that while the extraction of minerals is a necessary process it must also be considered a temporary use of land. In order to sustain the resourcefulness of the land, certain measures must ensure that mine sites are rehabilitated to a condition that is compatible with the surrounding environment. The study's primary purpose was to formulate a decision-making process embodied in different land management strategies that can be applied to derelict land, current workings and future operations. Cost-effective land management strategies are identified which endorse proper planning and progressive rehabilitation for all pits and quarries in Nova Scotia.

The secondary purpose of the study was to develop a methodology and criteria to identify potential demonstration rehabilitation projects. These would be an excellent way of demonstrating a provincial commitment toward rehabilitation of excavated land to local communities and the public at large. Some of this study's recommendations concern: (1) provincial land-use policy, including an amendment to the Planning Act; (2) mineral resource policy, including amendments to the Mineral Resources Act and the establishment of a Mineral Aggregates Act; (3) new departmental responsibilities, including a Surface Mining

Rehabilitation Division; and (4) information needs, including a conference or seminar on mine site rehabilitation, and a rehabilitation guidebook for industry and local government.

AQUACULTURE REVIEWS

The land-use planner also forms part of an interdepartmental review network for aquaculture licenses and experimental permits. The review process allows the department to screen proposed aquaculture sites to identify potential conflict with the exploration and mining sector. This is in keeping with the necessity to monitor all land and near-shore resource activity so as to maintain a relatively conflict-free land management practice. A database has been developed for aquaculture licence reviews to provide a system of data filing and retrieval for reference and review. Over 600 records are now entered into the database.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 13-14

DRILL CORE LIBRARIES[1]

J. D. Langille

The Nova Scotia Department of Mines and Energy (NSDME) maintains four core library facilities. Two facilities in Stellarton, Pictou County, are located on Bridge Avenue and on Acheron Court in the Stellarton Industrial Park. The Bridge Avenue facility has inside racks for core storage as well as wooden cabinets with trays holding vials of chip samples, mostly from hydrocarbon exploration wells. Covered outside core racks hold mainly core from coal exploration programs. A third facility, used partly for storing rock and other geological samples, is on Dakota Drive in the Debert Air Industrial Park, Colchester County. A fourth facility, equipped with dehumidifiers, is located near Malagawatch, Inverness County, and is used for storing core from a potash exploration program in that area.

Most core library activity is centred at the main and largest facility in the Stellarton Industrial Park. This facility consists of four buildings and provides storage for nearly 1½ million feet (457,200 m) of core. The newest of the buildings, opened in 1988, provides office and laboratory space for the drill core libraries staff. Core is received, organized, catalogued and palletized at this facility.

The total number of visitors, including staff, using the core library facilities in 1990 declined from 1989, but the number of individual cores examined, and the number of samples taken, both showed an increase (Table 1). The number of non-staff visitors, and the time spent by them at the Core Library, showed a marked increase over 1989.

Total holdings of core increased approximately 3% during 1990 (Table 2). The facilities are again approaching full capacity, although some core has now been selected for disposal. In order to accommodate new drill core in the future, it will be necessary to dispose of old core at the same rate as new core is received.

Table 1. Core Library statistics.

		1989	1990
USERS:	Non-Staff	78	92
	Staff	81	56
	TOTAL	159	148
USER DAYS:	Non-Staff	101	181
	Staff	336	128
	TOTAL	437	309
CORES EXAMINED		264	297
REFERENCE SAMPLES TAKEN		830	1188
DRILL CORES RECEIVED		200	198
METRES OF CORE RECEIVED		20 787	13 158

The Core Library staff is permanently located in Stellarton and only the Stellarton facilities are staffed on a full time, daily basis. Because most core, particularly at the main Industrial Park facility, is stacked and stored on wooden pallets and moved with a staff-operated fork-lift, some prior notice of an intended visit, usually 24 hours, is appreciated and at times is necessary. Proposed visits to facilities outside the Stellarton area should be requested at least 48 hours in advance. For further information on core library activities or requests to visit, please telephone Jim Langille, Core Library Supervisor, at (902) 752-4842 or John McMullin, Regional Geologist, at (902) 752-8429, FAX (902) 755-3158.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Cooperation Agreement on Mineral Development 1990-1992

Table 2. Drill core received by the Core Library in 1990.

COMPANY OR GROUP	LOCATION OF DRILLING	YEAR OF DRILLING	NUMBER OF HOLES	TOTAL METRES
Dresser Industries Inc.	Bass River, Colchester County	1983/84	10	157
Dresser Industries Inc.	Walton Mine, Hants County	Various	11	307
Durham Resources Inc.	West Gore, Hants County	1985-87	25	2,968
Durham Resources Inc.	Wine Harbour, Guysborough County	1985	2	400
ESSO Resources Canada Ltd.	Springhill, Cumberland County	1989	6	1,565
NSDME Mineral Resources Division	Boot Jack Bog, Guysborough County	1990	2 (1 in progress)	448
NSDME Mineral Development Division	Murchyville, Halifax County	1990	15	879
NSDME Energy Resources Division	Offshore Cape Breton Coal Program, Cape Breton County	1977-79	3 (part of)	12
NSDME Mineral Resources Division	Silver Mines, Cape Breton County	1990	3 (part of)	26
NSDME Mineral Resources Division	Tangier, Halifax County	1990	3 (1 in progress)	431
Nova Scotia Power Corporation	Glencoe, Inverness County	1990	2	149
Phelps Dodge	Silver Mine, Cape Breton County	mid-1960s	1	105
Public Works Canada	Ten Localities	n/d	85	315
Rosario Resources	Goldenville, Guysborough County	n/d	2	318
Scotia Prime Resources Inc.	Cameron Dam, Guysborough County	1988	1	88
Scotia Prime Resources Inc.	Lower Seal Harbour, Guysborough County	1987-88	4	764
Scotia Prime Resources Inc.	Otter Lake (Hwy. 224), Halifax County	1988	2	172
Torene Gold Explorations Inc.	Harrigan Cove, Halifax County	1987-88	3	788
Torene Gold Explorations Inc.	Meiklefield, Pictou County	1988	1	157
Torene Gold Explorations Inc.	Mitchell Brook, Guysborough County	1987	4	653
Torene Gold Explorations Inc.	Morvan, Antigonish County	1988	8	946
Westray Coal Inc.	Plymouth, Pictou County	1990	4	1,624
Wilco Mining Co. Ltd.	Wine Harbour, Guysborough County	1988	7	1,451
Government		(55%)	113	(15%) 2,260
Industry		(45%)	91	(85%) 12,463
TOTALS		(100%)	204	(100%) 14,723

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 15

MINERAL INVENTORY

N. A. Lyttle

BIBLIOGRAPHIC DATABASE ACTIVITIES

(J. M. Freeman, N. A. Lyttle, S. Saunders)

Indexing and on-line entry into GEOSCAN continued for Nova Scotia Department of Mines and Energy (NSDME) bibliographic records during 1990. GEOSCAN is a bibliographic database that provides access to publicly available geoscience literature concerning the Canadian landmass and offshore regions. The database presently contains over 140,000 records and is cooperatively produced from the indexing contributions of federal, provincial and professional geoscience organizations located throughout Canada. The Geological Survey of Canada, through the National GEOSCAN Centre, coordinates these indexing activities and provides computer resources in support of this project.

During the period 1 January 1990, to 31 December 1990, 591 new NSDME records were added to GEOSCAN. These records consisted of 299 assessment reports, 55 open file illustrations, 43 open file maps, 37 open file reports, 102 publications, 33 theses, 21 journal literature references and 1 internal document, representing a 5.3% increase in the Nova Scotia component of the database. As of 31 December 1990, the database contained 11,676 NSDME records consisting of 5220 assessment reports, 2349 publications, 1285 journal literature references, 1063 open file maps, 940 open file reports, 55 open file illustrations, 755 theses, 7 internal documents and 2 books.

The bibliographic index, Report 90-2: *Index to Assessment Reports, Publications, Open File Maps and Open File Reports for 1989*, was released in May 1990. Work on a ten-year index, covering the period 1981 to 1990, is in progress.

GEOLOGICAL AND GEOPHYSICAL MAPS DATABASE

(P. L. LeBlanc, N. A. Lyttle, J. M. Freeman)

During the summer and fall of 1990, a project was conducted to identify, index and enter into a database all pertinent information on published bedrock geology, surficial geology and airborne geophysical maps of Nova Scotia. Six data files have been created containing information on NSDME bedrock geology maps (52 maps), Geological Survey of Canada (GSC) bedrock geology maps (121 maps), Faribault-Fletcher Series bedrock geology maps (121 maps), NSDME and GSC surficial geology maps (31 maps), GSC colour total field and vertical gradient aeromagnetic maps (34 maps), and GSC red line total field and vertical gradient aeromagnetic maps (210 Maps).

The information in each data file, in the form of a data sheet for each map plus an index map showing the plotted location of each map in Nova Scotia with respect to the National Topographic System grid, was released as a series of open file reports (OFR 90-011 to 90-016) in January 1991. The open file reports are available in hard copy and on microfiche (index map plus data sheets), or as white prints (index maps only).

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 17-24

MINERAL EXPLORATION MONITORING ACTIVITIES

P. D. McCulloch

INTRODUCTION

Monitoring of mineral exploration activity in Nova Scotia is the responsibility of the Resource Geology Section of the Mineral Development Division. Staff assigned to this program consists of a regional geologist and a project geologist based in the regional office at Stellarton, Pictou County.

The monitoring process covers all exploration activities in the province and includes regular visits to company offices and exploration sites, liaison with industry personnel and reviews of current assessment reports and other material submitted by industry. Direct liaison with industry allows the department to maintain an awareness of current exploration activities throughout the province. Problems and difficulties that may need to be addressed by the department are identified and assistance or advice is provided if necessary. A statistical survey of exploration expenditures is compiled annually to obtain data on costs related to the various sectors of the mineral industry in Nova Scotia. In addition, all drill core generated in the province by the various mining exploration companies is recorded as part of the monitoring process. This core may be recovered for the Drill Core Library in Stellarton when no longer required by the companies.

MINERAL EXPLORATION ACTIVITY IN 1990

Mineral exploration and development work in Nova Scotia during 1990 remained at roughly the same level of activity as the previous year, although overall expenditures dropped from $22 million in 1989 to an estimated $10 million for 1990 (Fig. 1). The apparent discrepancy in expenditures versus activity can be explained by a partial shift from advanced exploration and development projects to lower budget grassroots programs. The current expenditure levels are roughly equivalent to the average expenditure

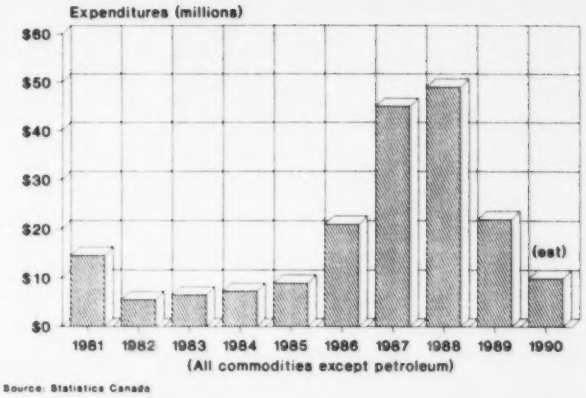

Figure 1. Exploration expenditures in Nova Scotia, 1981-1990.

levels of the 1970s and early 1980s.

A significant decrease in exploration for gold in the Cambrian and Ordovician Meguma Group was evident in 1990 as part of a trend which began in mid-1989. This decrease in activity was offset to a limited degree by an increase in gold exploration in other environments and by a renewed interest in base metals which saw market prices of the traditional metals strengthen significantly following mid-1987. Several companies that were active in gold exploration in the Meguma from 1986 to 1989 have shifted their emphasis to base metals.

Preliminary figures for the total number of general claims staked in 1990, including both exploration and development licenses, show a decrease of 29% from the previous year to 16,515 (Table 1). The number of claims staked for salt and potash and for coal remained low and essentially unchanged from 1989. A total of 19,213 claims for all commodities were in effect at the end of 1990, representing 695 exploration, development, coal, salt and potash, tailings and special licenses covering an area of 768,520 acres (1200 square miles or 3110 square kilometres), approximately 6% of the total area of the province. The amount of exploration drilling was down significantly in 1990, with the completion of approximately 20 000 m

Table 1. Details of exploration and development activity in Nova Scotia, 1982-1990. Parentheses around uranium claims indicate ground under alienation due to the uranium moratorium.

	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Exploration Expenditures	5,550,000	6,500,000	7,300,000	9,000,000	21,000,000	45,000,000	49,000,000	22,000,000	10,000,000
Total Licenses Issued (all catagories)	1193	1383	1082	1065	1314	2038	1641	937	695
Claims In Good Standing (new and reissued)									
General	38,466	39,903	25,858	27,636	35,661	53,860	38,367	21,957	16,515
Special (Order in Council)									
Salt and Potash	1,065	505	1,257	830	306	192	232	31	114
Coal	3,072	4,565	3,584	3,584	1,200	1,200	2,829	1,205	1,566
Tailings	--	--	379	375	375	0	0	0	116
Other	NA	NA	NA	NA	27	544	149	552	172
Uranium	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)	(1,200)
Development	1,160	1,325	1,251	1,245	801	1,006	1,216	864	730
Total (excluding closures and uranium licenses)	43,763	46,298	32,329	33,670	38,370	56,802	42,793	24,609	19,213
Total Area Held Under License (acres)	1,750,520	1,851,920	1,293,160	1,346,800	1,534,800	2,272,080	1,711,720	984,360	768,520
Work Reported For License Renewals ($)	4,107,273	4,200,210	2,625,666	2,389,351	9,954,013	26,905,676	29,612,880	31,333,645	16,569,640
Number Of Assessment Reports Received	124	188	140	108	154	271	406	303	176

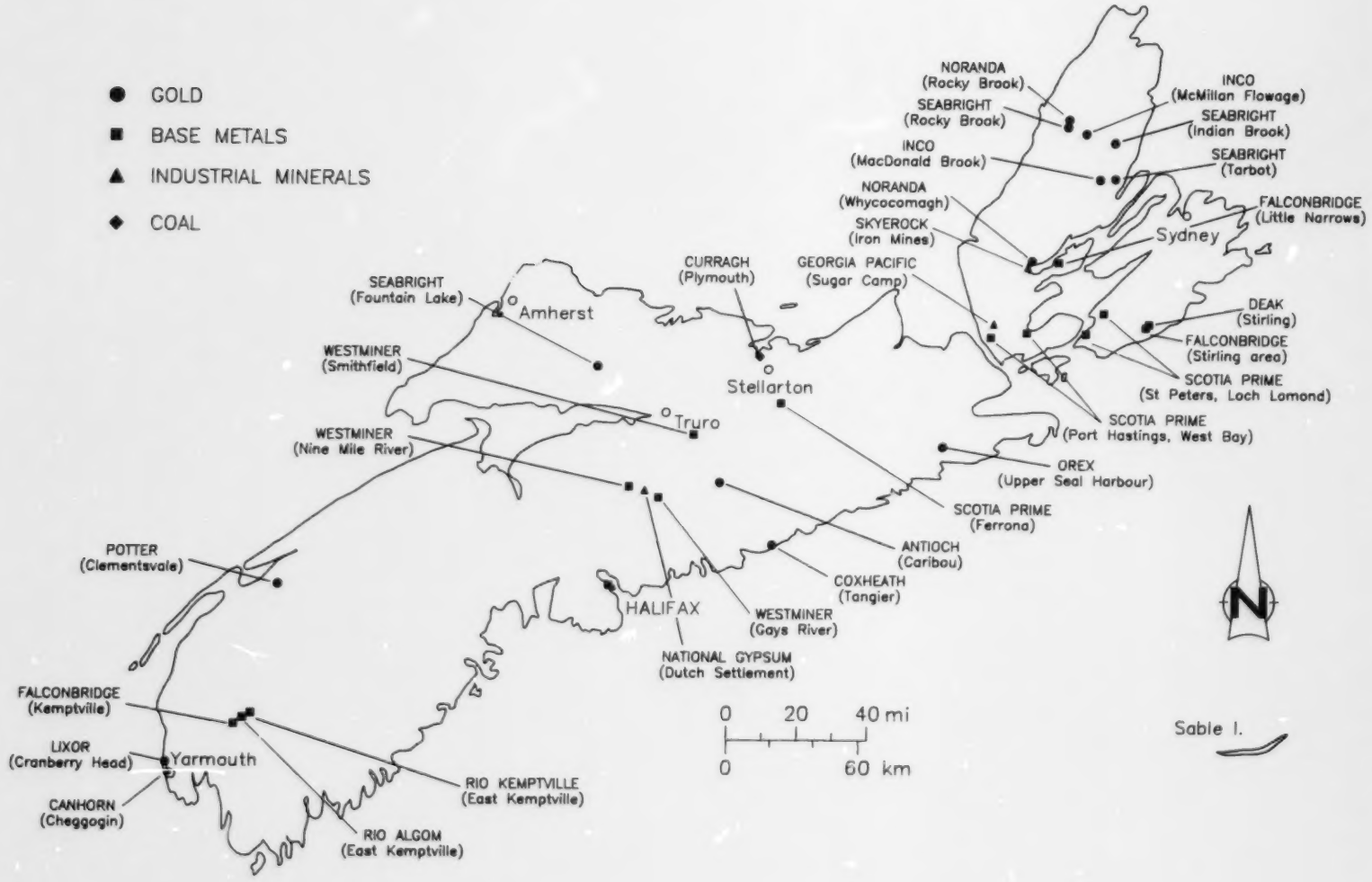

Figure 2. Exploration and development in Nova Scotia, 1990.

compared to a total of 42 000 m in 1989.

In addition, 11,871 claims formerly closed to exploration as a result of the uranium moratorium (742 square miles or 1921 square kilometres) were opened for general staking, except uranium, on 5 September 1990. A total of 226 claims remained closed to all staking because of identified uranium.

Approximately 220 companies and individuals held exploration interests (licenses or options) in the province in 1990, including 32 major, 31 junior and 29 private companies (Tables 2 and 3). In addition, several mining lease holders carried out exploration on their leases or on unclaimed ground where these commodities did not require licenses (e.g. limestone, gypsum). Organizations actively engaged in exploration and development work during 1990 included 17 major, 11 junior and 8 private companies as well as a number of individuals (Fig. 2 and Table 4).

EXPLORATION AND DEVELOPMENT ACTIVITIES

Gold

Exploration for gold continued to a limited degree in the historic gold mining districts of Halifax and Guysborough Counties in the southeastern mainland area of the Province. Work was concentrated on a detailed evaluation of two principal gold occurrences hosted by the Cambrian and Ordovician metasediments of the Meguma Group.

Exploration Orex Incorporated, in an option agreement with Onitap Resources Incorporated, completed underground drifting, diamond-drilling and bulk sampling on the Upper Seal Harbour property near Goldboro, Guysborough County. Antioch Resources (N.S.) Limited also completed additional underground exploration on the Caribou property in Halifax County consisting of crosscutting and rock sampling. Both of these projects were put on hold early in 1990 pending the raising of additional financing to continue the programs.

A significant increase in gold exploration was recorded in the Hadrynian to Cambrian volcanic and metasedimentary rocks of Victoria and Inverness Counties in the Cape Breton Highlands. Inco Exploration and Technical Services Incorporated continued a detailed exploration program consisting of trenching and diamond-drilling in the McMillan Flowage area east of Cheticamp. Seabright Explorations Incorporated carried out an exploration program including trenching and diamond-drilling on the Rocky Brook property southeast of Cheticamp and also completed prospecting and geochemical sampling in the Indian Brook and Tarbot areas along the east side of the highlands. Noranda Exploration Company Limited completed an exploration program consisting of trenching and diamond-drilling in the Campbells Brook area immediately north of Rocky Brook. Noranda's Exploration Division also completed a drilling program on a gold property near Whycocomagh in the southwestern area of the highlands.

Base Metals

Exploration for base metals demonstrated a modest increase in the level of activity during 1988-89 and this trend continued in 1990 with a number of projects completed throughout the province. The interest in base metals was highlighted in 1990 by the re-opening of the Gays River lead-zinc mine by Westminer Canada Limited. The deposit is hosted by Lower Carboniferous carbonates of the Windsor Group with a reserve estimate of 1.8 million tons grading 6.2% Pb and 10% Zn.

Several programs were undertaken in Windsor Group sedimentary rocks throughout northern mainland Nova Scotia and western Cape Breton Island. Westminer Canada Limited (Seabright Operations) continued a detailed evaluation of the Gays River lead-zinc mine including underground development drilling and sampling, and surface exploration drilling. The company also completed a detailed exploration program consisting of ground geophysics and diamond-drilling on the Smithfield lead-zinc deposit south of Truro.

Falconbridge Limited completed an airborne geophysical survey and additional diamond-drilling on the Jubilee lead-zinc property in Victoria County and Deak Resources Corporation completed an airborne geophysical survey over the Stirling mine property in Richmond County. Scotia Prime

Table 2. Major companies involved in mineral exploration in Nova Scotia.

	1988	1989	1990	Office location, 1990
BP Resources Canada Limited	x	-	x	Halifax
Canamax Resources Incorporated	-	-	-	
Cameco			-	
Cominco Limited			-	
Conwest Exploration Company Limited	-	-	-	
Curragh Resources Limited (Westray Division)	x	x	x	
Dominion Explorers Incorporated	-	-	-	
Domtar Incorporated	x	x	-	Windsor
Esso Resources Canada Limited	-	x	-	
Falconbridge Limited	x	x	x	Windsor
Fundy Gypsum Company Limited	x	x	x	Windsor
Georgia Pacific Corporation	x	x	x	River Denys
Granges Exploration Limited	x	x	-	
Hecla Mining Company of Canada Limited	x	x	-	
Husky Oil Operations Limited (through Scominex*)	x	x	x	
Inco Exploration and Technical Services Limited (manager of Scominex*)	x	x	x	Halifax
Interuranium Canada Limited (ground alienation)	-	-	-	
Lafarge Canada Incorporated	x	x	x	Brookfield
Murray Brook Resources Incorporated (formerly Northumberland Mines Ltd.)			-	Halifax
National Gypsum (Canada) Limited	x	x	x	Milford Station
Noranda Exploration Company Limited	x	x	x	
Nova Construction Company	-	x	-	Antigonish
Nova Scotia Resources Limited (through Scominex*)	x	x	x	
Nova Scotia Sand and Gravel Limited (division of L. E. Shaw Limited)	x	x	x	Lantz
NovaGold Resources Incorporated	x	x	-	
Phelps Dodge Corporation of Canada Limited			-	
Ridge Brokers Limited	-	x	-	
Rio Algom Exploration Incorporated	-	-	x	
Rio Algom Limited	-	x	x	
Scotia Limestone Limited	x	x	x	
Timminco Limited (Chromasco)	-	-	-	
Westminer Canada Limited	x	x	x	

x indicates work performed
- company inactive
* Scotian Mineral Exploration Venture

Table 3. Junior and private exploration companies in Nova Scotia, 1990.

	1988	1989	1990	Office location, 1990
Acadia Mineral Ventures Limited	*	*	*	Truro
Antioch Resources (N.S.) Limited	-	*	*	
Aquagold Resources Incorporated (formerly Torene Gold Exploration Limited)	*	*	*	Halifax
Arissig Explorations Limited	*	*	-	
Atlantic Goldfields Incorporated	*	-	-	
Aurion Minerals Limited	*	*	*	Halifax
Aurtec Mining Development Limited	*	*	*	
Belore Mines Limited	*	-		
Benrock Limited	-	*	*	Antigonish
Biron Bay Resources Limited	*	*		
Black Gold Enterprises Limited			-	
Bluestack Resources Limited	-	-	-	
BPR Holdings Limited			-	
Breakwater Resources Limited (formerly Novamin Resources Incorporated)	*	-	-	
Canhorn Mining Corporation			*	
Carbontec Industries Limited	*	*	*	Halifax
Carrick Gold Resources Limited	*	*	*	Dartmouth
Cobequid Resources Limited	*	*	-	Halifax
Coxheath Gold Holdings Limited	*	*	*	Bedford
Deak International Resources Limited (formerly Wilco Mining Company Limited)	*	*	*	
Donner Resources Limited		*	-	
Dynamic Consolidated Resources Limited	*	-	-	
Exploration Orex Incorporated	*	*	*	Goldboro
Explorer Industries Limited	-	*	-	Dartmouth
Fenorex Mineral Investigations Limited	*	*	-	Sydney River
Gedoro Mining Limited	*	-	-	Halifax
Giant Meguma Holdings	-	-	-	Halifax
Glenrock Investments	-	-	-	
Gold Bank Resources Limited	*	*	*	Enfield
Gold Brook Developments Limited	*	*	-	Margaree
Golden Shore Explorations	-	-	-	Bedford
Gordex Minerals Limited	*	-	-	
Greenstrike Gold Corporation	*	-	-	
Guinness Gold Resources Limited			*	
Gunnar Gold Incorporated	*	-		
Gusto Resources Limited	*	*	-	Halifax
Hathor Resources Limited	*	-	-	
Jascan Resources Incorporated	*	-	-	
Jovin Enterprises			-	
Kelly Rock Limited		*	-	
Kelrock Limited	*	*	*	Antigonish
Little Lake Gold Mines Limited	*	*	-	Dartmouth
Lisor Incorporated		*	*	
Lodestone Limited	*	*	-	Halifax
Lotus Resources Limited	*	*	-	Dartmouth
Macree Resources Incorporated	-	*	*	Dartmouth
MEX Explorations Limited	*	-	-	
Midas Minerals Incorporated	*	*	-	
Mill City Gold Incorporated	*	-	-	
Murgor Resources Incorporated			*	
Northumberland Mines Limited	*	-	-	
Oldham Resources Limited	*	*	-	
Onitap Resources Incorporated	*	*	*	
Orevco Incorporated	*	-		
Orient Resources Incorporated			*	
Orleans Resources Incorporated	*	-		
Outland Resources Corporation	-	-	-	
Pan East Resources Incorporated	*	-	-	
Petromet Resources Limited	*	-	-	
Renfrew Gold Contracting			*	
Scotia Prime Resources Limited	*	*	*	Halifax
Seabright Explorations Incorporated	*	*	*	Lower Sackville
Seascope Consultants Limited	*	-		
Skyerock Minerals Limited	-	-	*	Antigonish
Sunrise Metals Corporation	*	-		
Teraq Resources			*	Sydney
The Potter Mine (Nova Scotia) Limited	*	*	*	
Tri-Explorations Limited	*	*	*	Bedford
Tusk Minerals Limited	*	-		
United Reef Petroleums Limited	*	-	-	
Vando Enterprises			-	
W. Bruce Dunlop Limited	*	-	-	

* indicates work performed
- inactive

Table 4. Principal exploration and development programs, 1990.

COMPANY/LOCATION	COMMODITY	PROGRAM COMPLETED	CURRENT STATUS
Antioch Resources (N.S.) Limited Caribou, Halifax County	Gold	Underground cross-cutting, rock sampling	On hold
Canhorn Mining Corporation Chegoggin, Yarmouth County	Silica	Surface bulk sampling	Ongoing
Cashath Gold Holdings Limited Tangier, Halifax County	Gold	Additional analytical work	On hold
Curragh Resources Incorporated (Westray Coal Division) Plymouth, Pictou County	Coal	Underground development (construction of access tunnels, mine infrastructure)	Ongoing
Desk Resources Corporation Stirling, Richmond County	Base Metals	Airborne geophysical survey	-
Exploration Orex Incorporated Upper Seal Harbour, Guysborough Co.	Gold	Underground drifting, diamond-drilling and bulk sampling	On hold
Falconbridge Limited Jubilee, Victoria County	Base Metals	Geological mapping, airborne geophysics and diamond-drilling	Ongoing
Stirling, Richmond County	Base Metals	Geological Mapping, prospecting	-
Kempeville, Yarmouth County	Tin	Diamond-drilling	-
Georgia Pacific Corporation Sugar Camp, Inverness County	Gypsum	Diamond-drilling	Ongoing
Inco Exploration and Technical Services Limited, Cape Breton Highlands, Inverness and Victoria Counties	Gold	Geological mapping, trenching and diamond-drilling	-
MacDonald Brook, Victoria County	Gold	Geological mapping, prospecting	-
Lane Incorporated Cranberry Head, Yarmouth County	Gold	Diamond-drilling	Terminated
National Gypsum (Canada) Limited East Milford, Halifax County	Gypsum	Surface bulk sampling, diamond-drilling	Ongoing
Nevada Exploration Company Limited Rocky Brook, Inverness County	Gold	Geological mapping, basal till sampling and diamond-drilling	Ongoing
Whycocomagh, Inverness County	Gold	Diamond-drilling	Ongoing
Foster Misc (N.S.) Limited Clementsvale, Annapolis County	Gold, iron	Diamond-drilling	Ongoing
Rio Algom Exploration Incorporated East Kempville, Yarmouth County	Tin	Diamond-drilling	-
Rio Kempville Tin Corporation East Kempville, Yarmouth County	Tin	Diamond-drilling	-
Scotia Prime Resources Incorporated Windsor basin program	Base Metals	Detailed prospecting, rock sampling	Ongoing
Scotsgold Explorations Incorporated Rocky Brook, Inverness County	Gold	Trenching, ground geophysics and diamond-drilling	Ongoing
Indian Brook, Victoria County	Gold	Prospecting, geochemical sampling	Ongoing
Tarbot, Victoria County	Gold	Prospecting, geochemical sampling	Ongoing
Skyerock Minerals Limited Iron Mines, Inverness County	Magnetite	Surface bulk sampling	On hold
Westminer Canada Limited Gays River, Halifax County	Base Metals	Underground development drilling and sampling, surface exploration drilling	Ongoing
Smithfield, Colchester County	Base Metals	Geological mapping, ground geophysics and diamond-drilling	Ongoing
Nine Mile River, Hants County	Base Metals	Ground geophysics, diamond drilling	Ongoing

Resources Incorporated carried out detailed prospecting and rock sampling on several properties in northern Nova Scotia. Scotia Prime signed a conditional option agreement with Phelps Dodge Corporation of Canada Limited in December 1990 on an initial $1.65 million exploration program on three of these properties.

Rio Kemptville Tin Company carried out an exploration drilling program in the vicinity of the company's East Kemptville tin deposit in Yarmouth County and Rio Algom Exploration Incorporated completed a drilling program for tin immediately west of the East Kemptville deposit. An exploration drilling program for tin was also undertaken by Falconbridge Limited in the Kemptville area southwest of East Kemptville.

Industrial Minerals

Exploration for industrial minerals has demonstrated a modest growth in activity in recent years and is highlighted by the efforts of producers, particularly limestone and gypsum producers, to expand on current reserves as well as locate new deposits. The level of exploration activity during 1990 for the various industrial mineral commodities was down slightly compared to 1989.

Georgia-Pacific Corporation continued exploration drilling for gypsum in the vicinity of their quarry operation near Port Hawkesbury. The company is now shipping gypsum to the recently constructed Louisiana-Pacific Canada fibreboard plant at Port Hawkesbury. National Gypsum Company Limited completed surface bulk sampling and diamond-drilling on their gypsum property at East Milford, Halifax County. Skyerock Minerals Limited completed a surface bulk sampling program on a magnetite property at Iron Mines, Inverness County, and Canhorn Mining Corporation carried out surface bulk sampling on the Chegoggin silica deposit in Yarmouth County.

Coal

Exploration and development of coal resources in the province during 1990 continued at roughly the same level of activity as in recent years. Work was directed towards developing additional resources on currently producing properties as well as exploration for new resources in other coal basins.

Work on the Curragh Resources Limited (Westray Division) coal project at Plymouth, Pictou County, was resumed in the fall of 1990 following the completion of financial arrangements. Work is continuing on the preparation of surface facilities and mine infrastructure with a target date of mid-1991 to begin shipping coal. The company also carried out a seismic survey as part of an exploration program for coal in the Debert - Kemptown coal basin. The Cape Breton Development Corporation continued exploration and development drilling in advance of coal mining operations in the Sydney coal basin.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 25-26

CORE LIBRARY ACTIVITIES[1]

B. Palmer

Work was maintained during 1990 on the evaluation of large drill core packages located in the core library at the Stellarton Industrial Park. This program was conducted from 1985 to 1989 under the Canada-Nova Scotia Mineral Development Agreement and continued in 1990 under the Canada - Nova Scotia Cooperation Agreement on Mineral Development. The project has been carried out by project geologist Bill Palmer, assisted by mineral technician Joe O'Leary. The purpose of the project is to thoroughly investigate the quality and quantity of core obtained from a given area or drilling project, ensure that all related data are available, and make recommendations for the disposal of core that does not meet the desired criteria for permanent retention.

Since the beginning of this program in September 1985, evaluations have been made and reports written on large volumes of core from the Getty - Gays River lead deposit in Halifax and Colchester Counties (12 102 m), the Walton barite and base metal deposit in Hants County (13 160 m), the Meaghers Grant area in Halifax County (2713 m), the Kaiser celestite deposits at Enon Lake in Cape Breton County (10 098 m) and the Yava lead deposit at Salmon River in Cape Breton County (23 296 m). Evaluation of the Yava deposit began in 1989 and continued until June 1990. Approximately 5500 m of core were examined from January to June 1990. Also evaluated during 1990 was a package of Algas (Novacorp Engineering) diamond-drill core (3234 m) and 2340 m of exploration core drilled by the Magnet Cove Barium Corporation in various locations in Nova Scotia, predominantly near the Walton mine area.

Various recommendations have been made by core library staff for the retention and disposal of diamond-drill core according to the classification of drill core source. These classifications and recommendations are as follows:

Classifications of diamond-drill programs:
a. Exploration
b. Exploration/development
c. Active mine
d. Abandoned mine with significant reserves
e. Abandoned mine with no or insignificant reserves
f. Geotechnical
g. Isolated drillholes or small projects with five or fewer holes.

Recommendations for retention or disposal of diamond-drill core:
a. All core that has been designated for permanent storage should, if possible, be maintained in its entirety and present condition.
b. All core that has been designated for disposal should be listed and the list distributed to departmental staff and outside potential users before discarding.
c. Sampling, if necessary, should only be done under the supervision of the core library staff. The samples should be recorded and the results returned to the department.
d. A periodic review should be made to re-assess the permanent core for possible disposal.
e. Consideration should be given to reducing the core from certain drillholes by selecting representative samples. This could reduce the amount of core from these holes by as much as 90%.
f. All core should be photographed.

No large scale disposal of core has yet taken place; however, recommendations for disposal of as much as 60% of the evaluated core lots have been made available in various internal reports. Disposal

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Cooperation Agreement on Mineral Development 1990-1992

of diamond-drill core that has been identified through this process as being in excess of the core library's need will take place after the reports have been circulated and discussed by a committee of departmental representatives. The main reason for disposing of core is redundancy. The presence of mixed or missing core and unidentified or unmarked core boxes has led to disposal of minor amounts of core.

Initially, an integral goal of the core evaluation program was to photograph all the diamond-drill core that was to be discarded. This has now been expanded to include all core that has been brought into the core library. Photographing the core on 35 mm slides will enable the department to maintain a permanent visual record of all diamond-drill core, particularly core that may be discarded, sampled or accidentally spilled. The department is presently in the process of setting up a permanent photography area in the Core Library where core can be quickly and efficiently processed.

To date, the Meaghers Grant core has been photographed, experimenting with various camera and light settings. Each photograph or slide contains four core trays which, depending on size, can contain from 60 (HQ) to 100 (AQ) feet of core. These slides will be kept in files with other pertinent data on diamond-drilling and will be available for viewing at the core library.

Mineral Development Division, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 27-32

THE THERMAL EVOLUTION OF THE MARITIMES BASIN: EVIDENCE FROM APATITE FISSION TRACK ANALYSIS[1]

R. J. Ryan, A. M. Grist[2] and M. Zentilli[2]

INTRODUCTION

This paper summarizes the preliminary results of apatite fission track studies in the Maritimes Basin of eastern Canada. Apatite fission track analysis is based on the measured density and etchable length distribution of linear tracks of crystal damage produced during the spontaneous fission decay of trace amounts of ^{238}U in apatite (e.g. Wagner, 1968; Gleadow and Duddy, 1981). Fission track densities provide a measure of mineral age with respect to the closure temperature for track retention (80-130°C). Corresponding etchable track length distributions contain valuable information on the thermal history of the mineral because decrease in track length by annealing of the fission track damage is a thermally activated process.

The apatite fission track method is gaining prominence as a valuable technique for assessment of the level of maturation of hydrocarbon-prone strata for the following reasons:

(1) the presence of detrital apatite in sandstone makes the fission track method useful over a wide range of depositional settings;

(2) the range of temperatures over which the thermal annealing of fission tracks in apatite occurs is approximately the same as the range of temperatures at which liquid hydrocarbons are generated, and therefore the method is capable of detecting slight variations in the level of thermal maturity of strata; and

(3) unlike most conventional maturation indicators, which are only able to assess the composite effects of time and temperature, the apatite fission track method is able to separate the relative contributions of these components to the overall maturity. This provides a powerful tool in constructing thermal history models of sedimentary basin.

The Maritimes Basin (Fig. 1) is an upper Paleozoic basin containing an abundance of mineral and energy resources. The potential for extensive undiscovered resources is high, but the success of future exploration will depend on a better understanding of the metallogenesis and hydrocarbon migration within the context of basin development and thermal evolution. This paper examines new constraints to possible models for the origin and evolution of the basin and its resources, based primarily on apatite fission track analyses and organic maturation.

The Maritimes Basin is a large basin (approx. 650 000 km^2); however, it is only an erosional remnant of a much larger basin of Carboniferous through Permian sedimentation (Van de Poll, 1973). The basin evolutionary models proposed to date (e.g. Poole, 1967; Belt, 1968; Webb, 1969; Bradley, 1982) are not constrained by thermal data and do not take into account the erosional history of the basin. A complete understanding of the basin evolution is not possible without a reconstruction of the basin prior to erosion. Information that can permit such a reconstruction is derived primarily from thermal imprints on the extant sedimentary rocks and contained organics. The thermochronology is therefore pivotal to any interpretation of basin evolution.

This paper reviews the results of apatite fission track analysis of samples from wells in the offshore Gulf of St. Lawrence area and samples from the Cumberland Basin (south-central part of the

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Cooperation Agreement on Mineral Development 1990-1992 and by research grants to M. Zentilli, Dalhousie University, including Department of Supply and Services (Canada) contracts and a grant from ESSO Canada Inc.

2 Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5

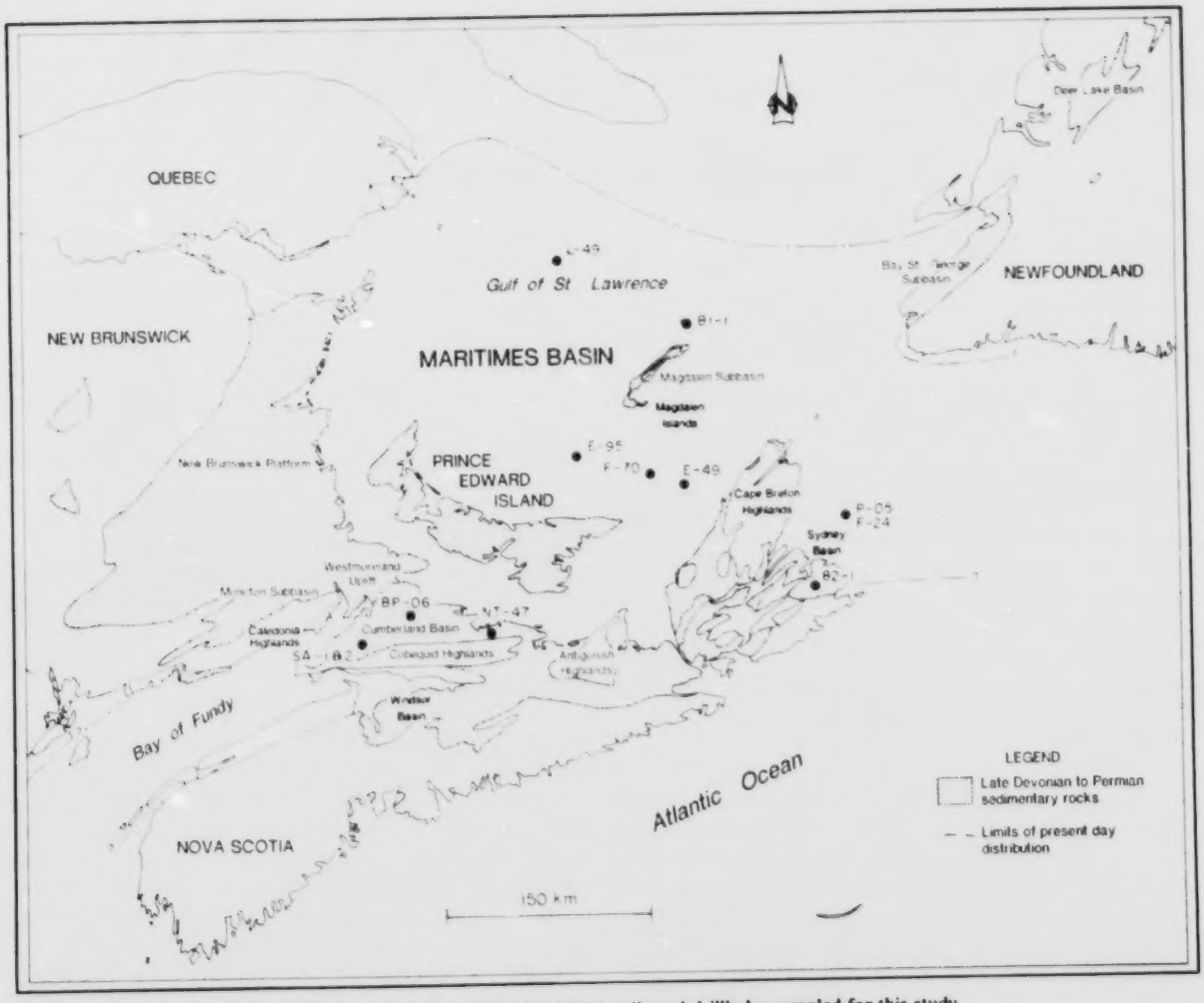

Figure 1. The Maritimes Basin of Atlantic Canada and location of the wells and drillholes sampled for this study.

Maritimes Basin). Thermochronological studies of the Cumberland Basin have been integrated with the extensive stratigraphic, sedimentologic and structural database documented over the last few years (Ryan *et al.*, in press). Time - temperature data for the Cumberland Basin area are be used to help interpret the more regional fission track and organic maturation data from elsewhere in the Maritimes Basin.

THE MARITIMES BASIN

The Paleozoic of the Atlantic region forms a folded belt of sedimentary, metamorphic and igneous rocks which constitute the northeastern part of the Appalachians. The earliest folding of Paleozoic strata in the area took place in the Ordovician Taconic Orogeny. Subsequent folding, faulting, intrusion and metamorphism during the Devonian Acadian Orogeny stabilized the Appalachian "Geosyncline", which presently extends to the edge of the continental shelf (Poole, 1967). The Carboniferous to Permian system of eastern Canada comprises a post-Acadian molassic suite of coarse- to fine-grained terrestrial and shallow marine clastic, carbonate, evaporite and volcanic rocks. It underlies an irregular area of lowland extending from eastern Maine to Newfoundland (Fig. 1).

Van de Poll and Ryan (1985) suggested that the Maritimes Basin should not be thought of as a single post-orogenic basin, but rather as a "composite basin", consisting of a group of interconnected fault

block basins and horsts which at various times underwent different rates of subsidence and uplift. Additional fragmentation of the depositional basin into structural basins (sub-basins) took place along a series of faults both during and subsequent to basin development.

STRATIGRAPHY

This study concentrates on the post-Visean rocks that have been intersected by wells and deep drill-holes in the basin. The stratigraphy of the Maritimes Basin has recently been revised and simplified by Ryan *et al.* (in press). These revisions, based on work in the Cumberland Basin, change the emphasis of the traditional nomenclature (Bell, 1944) from chronostratigraphic and biostratigraphic units to lithostratigraphic terminology. Many of the group names have been retained; however, they have been redefined. Although there are over 20 km of composite stratigraphic section, the basin-fill preserved in any one area rarely exceeds 7 km in thickness.

Following are brief descriptions of the units intersected by the wells being studied, from oldest to youngest. The Windsor Group comprises a marine sequence of clastics, carbonates and evaporites. The evaporites are often deformed into diapiric structures. The Mabou Group, which replaces the name Canso Group (abandoned), is a predominantly fine grained clastic sequence of red and grey floodplain and lacustrine strata. The Cumberland Group, as redefined by Ryan *et al.* (in press), includes all of the predominantly grey, coal-bearing strata of the basin. The Cumberland Group includes thick basin margin fanglomerates and sand-dominated sequences. Although the overall sequence is grey, local units of red strata are interstratified with the coal-bearing strata. The Cumberland Group, as redefined, generally includes all of the strata previously assigned to the Morien, Riversdale and Stellarton groups and all of the grey coal-bearing strata previously assigned to the Pictou Group. The Pictou Group is a redbed-dominated sequence of fluvial rocks which overlies the Cumberland Group strata throughout most of the basin. The Pictou Group redbeds are a major component of the section in the Gulf of St. Lawrence area where more than 3000 m can be present. These red, non-coal-bearing strata include the Prince Edward Island redbeds and the redbed sequence in the offshore portion of Sydney Basin.

APATITE FISSION TRACK ANALYSIS

Samples

The samples used in this study were obtained from cuttings and cores from offshore wells, and onshore diamond-drill holes and outcrops in order to have a reasonable geographic and stratigraphic distribution from the basin (Fig. 1). The samples are from the early Late Carboniferous to Early Permian Cumberland and Pictou groups. They are primarily from conglomerate or coarse sandstone and those from wells and drillholes were selected to correspond as closely as possible to vitrinite reflectance samples (Fig. 2).

Analytical Procedures

Apatite mineral separates were obtained using standard heavy liquid and magnetic mineral separation techniques. The individual separates (generally less than 200 grains) were mounted in epoxy and polished to expose internal grain surfaces. Spontaneous tracks were revealed by etching in 7% HNO_3 for 40 seconds at 25°C. Fission track ages were determined using the external detector method (Fleischer *et al.*, 1965; Hurford and Green, 1982). A thin sheet of low-uranium muscovite was placed in intimate contact with the polished surface of each grain mount to serve as a neutron-induced fission fragment detector. Samples were irradiated at either the McMaster University nuclear reactor, or at the Dalhousie University Slowpoke reactor in the presence of a glass neutron dosimeter of known characteristics.

The thermal-neutron fluence obtained was approximately 5×10^{15} neutrons/cm^2 in the McMaster reactor and 9×10^{15} neutrons/cm^2 in the Dalhousie reactor. Track densities (tracks/cm^2) for both spontaneous and induced fission track populations were measured at 1250X magnification (100X dry objective, 12.5X oculars). Fission track ages were calculated using a weighted mean zeta calibration factor (Fleischer *et al.*, 1975; Hurford and Green, 1983), determined using the Fish Canyon Tuff apatite (obtained from C. W. Naeser), and Durango and Renfrew apatites (obtained commercially) as age calibration standards.

Etchable length distributions of horizontal,

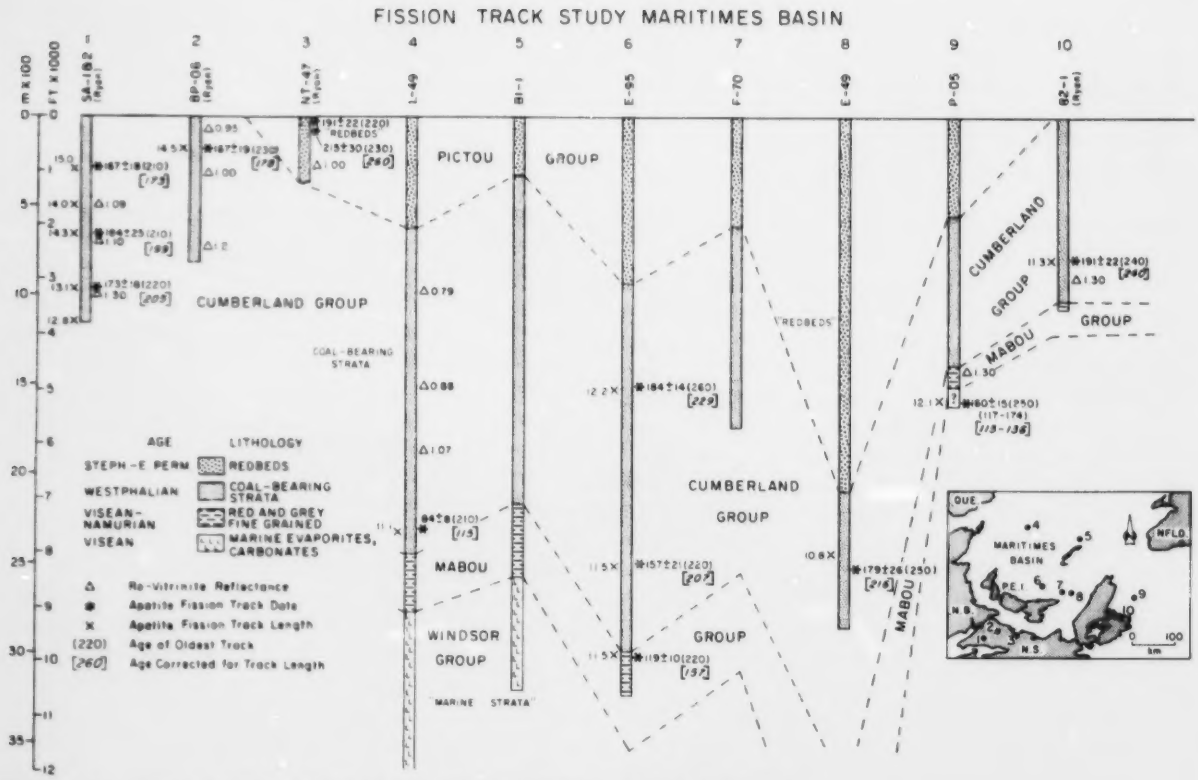

Figure 2. Cross-section of drillholes and wells used in this study and data obtained from analyses.

confined tracks in crystallographic planes parallel to the c-axis were measured at 1562.5X magnification (100X dry objective, 12.5X oculars, 1.25X microscope tube) using a digitizing pad interfaced with a personal computer. Horizontal confined tracks are internal fission tracks that are subparallel to the mineral surface. Positioning of the mouse (with an attached LED) on the digitizing surface was made possible by attaching a projection tube to the microscope. The precision of each individual track length measured is approximately + 0.15 microns.

RESULTS

Figure 2 is a cross-section of drillholes and wells used in the study. The following inferences may be made from the data:

(1) the overall corrected ages of the oldest tracks range from 210 to 260 Ma, which are all younger than the strata and indicate that apatite has been reset;

(2) uncorrected ages decrease with depth (see E-95 in Fig. 2), although this trend is not obvious in some of the shallower holes because the stratigraphic interval sampled is too limited;

(3) samples obtained from present-day depths of 2.5 to 3 km have finite (greater than 0) ages; and

(4) the youngest uncorrected age (84 ± 8 Ma; L-49 Bradelle) corresponds to anomalously low vitrinite reflectance values. Additional sampling would be justified to determine if there were unusual heat flux conditions in the northwest portion of the Maritimes Basin.

DISCUSSION

The data can be interpreted (cf. Grist *et al.*, in press) to indicate that:

(1) The basin underwent rapid sedimentation and burial from about 320 to 290 Ma (Late Carboniferous);

(2) there was a basin-wide erosion event that lasted from 270 to 200 Ma (Early Permian to Early Jurassic) and removed 1-3 km of strata;

(3) there was a slow unroofing (erosion) event from 200 to 100 Ma (Early Jurassic to Early

Cretaceous);

(4) over the last 100 million years the erosion rate has been very slow;

(5) there is no evidence of Triassic sedimentation or thermal activity in any of the samples from the basin studied to date; and

(6) the paleogeothermal gradient, as interpreted from the time-temperature index calculations on the three wells sampled, was approximately 22-27°C/km, contrasting with gradients up to 67°C/km suggested by Hacquebard (1984); the finite age of the samples from depths of 2.5 to 3.0 km also suggests that the present gradient is approximately 25°C/km.

If the interpretations above are correct then the Maritimes Basin must have covered most the Atlantic Canada region 290 Ma, prior to erosion of the 1-3 km of sedimentary cover. Figure 3 is a cartoon of the possible extent of the Maritimes Basin at various times in its history. Further documentation of this sedimentary cover can be derived from additional fission track samples within the basin strata and from the surrounding highland regions. Argon dating of the basin strata and surrounding highland areas might also more closely constrain the extent of the sedimentary cover during the Early Permian in the Maritimes Basin. The implications of this study for petroleum and mineral resource exploration are the subject of continued research; however, preliminary results indicate that the timing of maximum temperatures, and therefore basin brine expulsion events, in the basin can be well constrained by combining apatite fission track analysis with the stratigraphic and organic maturation data.

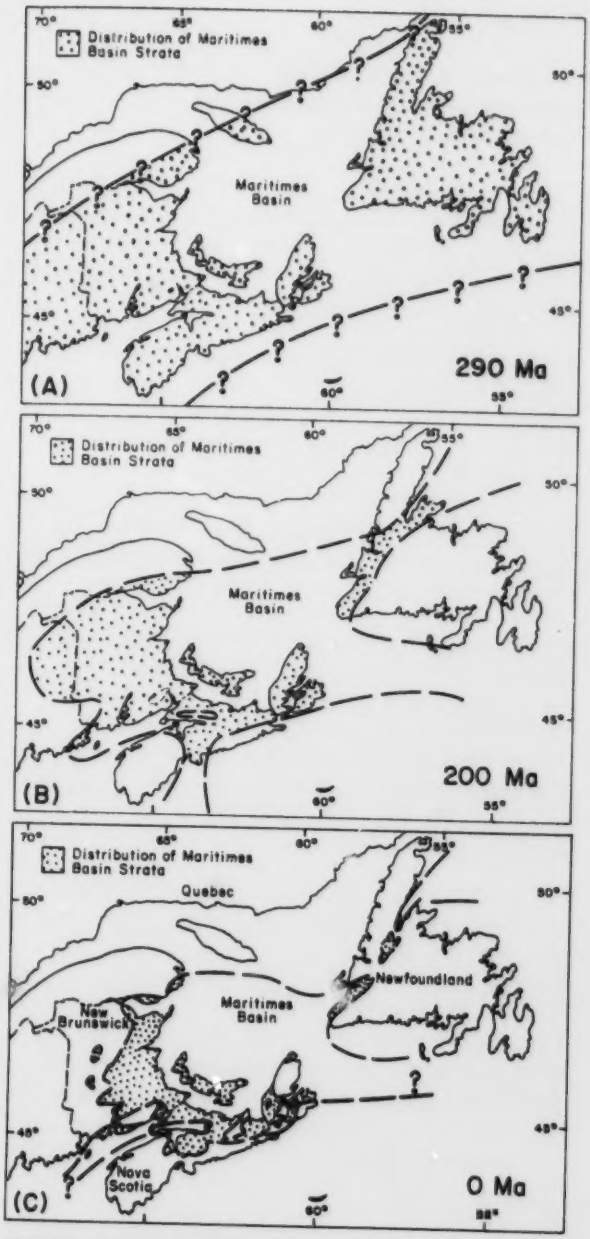

Figure 3. Cartoon showing the possible extent of the Maritimes Basin 290 Ma, 200 Ma and at present.

REFERENCES

Bell, W. A. 1944: Carboniferous rocks and fossil floras of northern Nova Scotia; Geological Survey of Canada, Memoir 238, 277 p.

Belt, E. S. 1968: Post-Acadian rifts and related facies, Eastern Canada; *in* Studies of Appalachian Geology, Northern and Maritime, eds. Ean Zen *et al.*; New York, Interscience Publications, New York, p. 95-113.

Bradley, D. C. 1982: Subsidence in Late Paleozoic basins in the northern Appalachians; Tectonics, v. 1, p. 107-123.

Fleischer, R. L., Price P. B. and Walker, R. M. 1965: Tracks of charged particles in solids; Science, v. 149, p. 383-393.

Fleischer, R. L., Price, P. B. and Walker, R. M. 1975: Nuclear Tracks in Solids - Principles and Applications; Berkley, University of California

Press, 605 p.

Gleadow, R. and Duddy, A. 1981: A natural longterm annealing experiment for apatite; Nuclear Tracks, v. 5, p. 169-174.

Grist, A., Ryan, R. J., Zentilli, M., Donelick, R. and Beaumont, C. in press: Thermal history of the Maritimes Basin, evidence from fission track analysis; *in* Report of Activities, Part B; Geological Survey of Canada, Paper 91-1B.

Hacquebard, P. A. 1984: Coal rank changes in the Sydney and Pictou coalfields of Nova Scotia, causes and significance; Canadian Institute of Mining and Metallurgy Bulletin, v. 77, no. 865, p. 33-40.

Hurford, A. J. and Green, P. F. 1982: A user's guide to fission track dating calibration; Earth and Planetary Science Letters, v. 59, p. 343-354.

Hurford, A. J. and Green, P. F. 1983: The Zeta age calibration of fission track dating; Isotope Geoscience, v. 1, p. 285-317.

Poole, W. H. 1967: Tectonic evolution of the Appalachian region of Canada; Geological Association of Canada, Special Paper 4, Hugh Lilly Memorial Volume, p. 9-51.

Ryan, R. J., Boehner, R. C. and Calder, J. in press: Lithostratigraphic revisions of Upper Carboniferous strata of the Cumberland Basin: Implications for the Maritime Basin; Canadian Society of Petroleum Geologists Bulletin.

Van de Poll, W. H. 1973: Sediment dispersal patterns and lithofacies variation in the Pennsylvanian Pictou Group of New Brunswick; Maritime Sediments, v. 9, p. 72-79.

Van de Poll, H. W. and Ryan, R. J. 1985: Lithostratigraphic, physical diagenetic and economic aspects of the Pennsylvanian to Permian transition sequence of Prince Edward Island and Nova Scotia; Geological Association of Canada, Guidebook 14, 109 p.

Wagner, G. A. 1968: Fission track dating of apatites; Earth and Planetary Science Letters, v. 4, p. 411-415.

Webb, G. W. 1969: Paleozoic wrench faults in the Canadian Appalachians; *in* North Atlantic Geology and Continental Drift, ed. M. Kay; American Association of Petroleum Geologists, Memoir 12, p. 754-786.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 33

CORE LIBRARY DATABASE[1]

D. Weir

Early in 1990 a database was set up in Advanced Revelation® at the NSDME core library. This database was designed for cataloguing the drill core stored at the Core Library. Core Transfer Reports used to record additions and deletions are also in this database so that any new core received by the Department of Mines and Energy will automatically be entered into the core catalogue.

To date the core from two buildings has been completely listed with as much information on each hole as can be obtained from the labels on the pallets or box ends. In some cases hole numbers, footage, or box numbers cannot be seen without more detailed work on each individual core by removing it from the pallet. This process is very time consuming, and in some cases the core still cannot be identified, so a preliminary list from the readily available information is being completed first. The additional information will be added later when the core is processed in detail by the core library staff or when accessed by a client.

So far, there are 411 records, with each record containing the following fields: Reference, Company, Location, Year, Holes (Interval, Core Size, Box Numbers), Storage, Temporary Storage, Number of Pallets, Number of Boxes and Notes. The 'Reference' (or Key), is a sequential number automatically assigned to each record by the computer. 'Company' refers to the company, government agency or individual that the hole was drilled for. 'Location' is the geographic position where the hole was drilled. 'Year' is the year the hole was drilled. 'Holes' refers to the hole designation and includes the interval of drilling, the size of the core and the box numbers. 'Storage' is the building, row and stack where the core is stored. 'Temporary Storage' is the location of core not yet assigned a permanent storage position, or of core removed from storage for use or examination. 'Number of Pallets' refers to the number of pallets used to store the listed core. 'Number of Boxes' is the quantity of boxes in a series of holes on a report. 'Notes' may include sampling records, missing core or other special conditions and significant information.

These records can be accessed individually by the key number or reference, giving the record of a drillhole or a particular group of holes. Also, the core listing can be searched by any one or more of the fields in the record. For example, if a company drilled in a specific location, the holes could be listed by naming the company in the appropriate field and the location in its field. This would list all the holes drilled by this particular company in the specified location.

In the two buildings completed there are over 1300 pallets, containing more than 32,000 boxes of core. The preliminary list of the remaining two buildings should be completed by mid-1991 when a print-out listing the core by the above fields will be available. This database and catalogue will considerably increase the efficiency of handling clients' requests and will provide a comprehensive record-keeping system for usage and sampling.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Cooperation Agreement on Mineral Development 1990-1992

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 35-36

CARBONIFEROUS BASINS PROJECT ACTIVITIES, 1990

R. C. Boehner

New field project activities were not undertaken in 1990 in order to alleviate the backlog of unreleased project work. Following the recent conclusion of the Cumberland Basin Project (Canada - Nova Scotia Mineral Development Agreement 1984-1989) a set of four full-colour, 1:50 000 scale geological maps by Ryan and Boehner (1990) and Ryan *et al.* (1990a-c) has been released (Nova Scotia Department of Mines and Energy Maps 90-11 to 90-14). The complementary report on the geology of the Cumberland Basin by R. J. Ryan and R. C. Boehner is under review. In addition, a set of three, two-colour (green on black), 1:1600 scale geological maps of the Canadian Salt Company Limited Pugwash Mine, by D. C. Carter (1990), has been released (Nova Scotia Department of Mines and Energy Maps 90-1 to 90-3). The complementary report on the geology of the Pugwash salt deposit by D. C. Carter is in a first draft stage. Basic geological data on Nova Scotia Department of Mines and Energy Drillhole LMA88-1 drilled for stratigraphic information near Lower Maccan in the Cumberland Basin were released as Nova Scotia Department of Mines and Energy Open File Report 90-010 (Boehner, 1990a).

Current mineral exploration activities in the Carboniferous basins of Nova Scotia suggested the need for a readily available source of references on the geology and mineral deposits of these basins. Open File Report 90-023 (Boehner, 1990b) was released as a selected bibliography highlighting reports, papers and maps produced in the 1970s and 1980s. Three Open File Map sets (OFM 91-002, 23 maps and 1 legend; OFM 91-003, 5 maps and 1 legend; and OFM 91-004, 19 maps and 1 legend) containing the 1:15 840 scale field geology maps for the Shubenacadie and Musquodoboit basins, Loch Lomond Basin and Glengarry Half-graben, and the Sydney Basin were released in early 1991 (Giles *et al.*, 1991, Boehner and Giles, 1991, and Boehner and Prime, 1991).

REFERENCES

Boehner, R. C. 1990a: Drillhole LMA88-1, Lower Maccan, Cumberland County; Nova Scotia Department of Mines and Energy, Open File Report 90-010.

Boehner, R. C. 1990b: Selected bibliography of the the geology (including economic geology) of Carboniferous basins in Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Report 90-023, 33 p.

Boehner, R. C. and Giles, P. S. 1991: Geological Field Maps of the Sydney Basin, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Map 91-004, 19 maps and 1 legend, scale 1:15 840.

Boehner, R. C. and Prime, G. 1991: Geological Field Maps of the Loch Lomond Basin and Glengarry Half-Graben, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Map 91-003, 5 maps and 1 legend, scale 1:15 840.

Carter, D. C. 1990: Geology of the Canadian Salt Company Limited Pugwash Mine, Pugwash, Nova Scotia; Nova Scotia Department of Mines and Energy, Map 90-1 (630 level), Map 90-2 (730 level) and Map 90-3 (830 level), scale 1:1600.

Giles, P. S., Boehner, R. C. and Ryan, R. J. 1991: Geological Field Maps of the Shubenacadie and Musquodoboit Basins, Nova Scotia; Nova Scotia Department of Mines and Energy, Open File Map 91-002, 23 maps and 1 legend, scale 1:15 840.

Ryan, R. J. and Boehner, R. C. 1990: Cumberland Basin Geology Map, Tatamagouche and Malagash, NTS 11E/11 and 11E/14; Nova Scotia Department of Mines and Energy, Map 90-14, scale 1:50 000.

Ryan, R. J., Boehner, R. C., Calder, J. H. and Deal, A. 1990a: Cumberland Basin Geology Map, Amherst, Springhill and Parrsboro, NTS 21H/8, 9

and 16; Nova Scotia Department of Mines and Energy, Map 90-12, scale 1:50 000.

Ryan, R. J., Boehner, R. C. and Deal, A. 1990b: Cumberland Basin Geology Map, Apple River and Cape Chignecto, NTS 21H/7 and 10; Nova Scotia Department of Mines and Energy, Map 90-11, scale 1:50 000.

Ryan, R. J., Boehner, R. C. and Deal, A. 1990c: Cumberland Basin Geology Map, Oxford and Pugwash, NTS 11E/12 and 11E/13; Nova Scotia Department of Mines and Energy, Map 90-13, scale 1:50 000.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 37-47

SEISMIC INTERPRETATION, POTENTIAL OVERTHRUST GEOLOGY AND MINERAL DEPOSITS IN THE KENNETCOOK BASIN, NOVA SCOTIA[1]

R. C. Boehner

INTRODUCTION

Thrust fault structures in the Carboniferous basins of Nova Scotia have been postulated or identified at a variety of scales and in increasing numbers by previous workers (see Smith and Collins, 1985, and Boehner, in press). The association of thrust faults with mineral occurrences is not new to the area, Smith and Collins (1985) described these and other structures in the context of mineral deposits and a pattern indicative of large-scale thrusting is gradually emerging. A genetic relationship between late Carboniferous tectonics and metallogenesis in the sedimentary basins of Nova Scotia is currently an attractive concept (Boehner and Ryan, 1990, and references therein). This report is an interpretation of recently released seismic lines by Chevron Canada Ltd. in the Kennetcook-Noel area (Fig. 1) in the eastern part of the Kennetcook Basin, and an integration of these seismic lines into the basin as a whole.

Fault and fracture systems are important conduits for the mineralizing fluids that generate mineral deposits. Carbonate-hosted base metal and barite mineral occurrences are commonly associated with the Windsor Group - Horton Group contact in the area south of the Cobequid - Chedabucto Fault System and subsidiary faults extending into the Nova Scotia (Meguma) Platform (Fig. 2). This relationship is complicated by the protracted history of movement on the Cobequid - Chedabucto Fault System both during the late Paleozoic (dextral) and subsequently in the Mesozoic (sinistral). Later fault movement and related deformation subsequently contributed to locally severe disruption of the deposits.

Although recent models for these deposits have focused on formation during the middle to late Carboniferous (Westphalian) peak of tectonic activity on the Cobequid - Chedabucto Fault System (Boehner and Ryan, 1990), an earlier (possibly Viséan) sedimentary exhalative origin is also possible. For example, if overthrusting postdates the mineralizing event that generated the Walton deposit, then the potential for blind mineral deposits of the Walton type (Cu, Pb, Zn, Ag and Ba) may offer significant new mineral exploration opportunities. Therefore, it is not critical whether the deposits are sedimentary exhalatives or not.

GEOLOGICAL SETTING

The Kennetcook Basin (Fig. 2) is the most northerly structural basin within the Minas Sub-basin of Bell (1929, 1958). The area is bounded to the north by the east-west Cobequid - Chedabucto Fault System and by the partially superposed Mesozoic rocks of the Fundy Rift, a half-graben faulted on the north side and submerged beneath the waters of Minas Basin. The basin follows the regional northeast-trending structural fabric in the Meguma Platform. The northeast fabric merges to the north with the east-west Cobequid - Chedabucto Fault System and is truncated by the Mesozoic rocks. The southern border of the basin is the Rawdon Fault (Fig. 3), which is a major fault with Meguma Group turbidites and, locally, Horton Group continental rocks constituting the Rawdon Block. The tectonic and sedimentary history along the Cobequid - Chedabucto Fault System is long and complicated, and a detailed description is beyond the scope of this paper. Generally, however, the late Carboniferous (Namurian to Westphalian) was a particularly active time for dextral wrench motion on the fault system and its subsidiary northeast-southwest faults. In divergence areas, such as the

1 This work was originally presented as a poster at the Atlantic Geoscience Society Annual Meeting and Colloquium, Current Research in the Atlantic Provinces, held in Amherst, Nova Scotia, February 1991

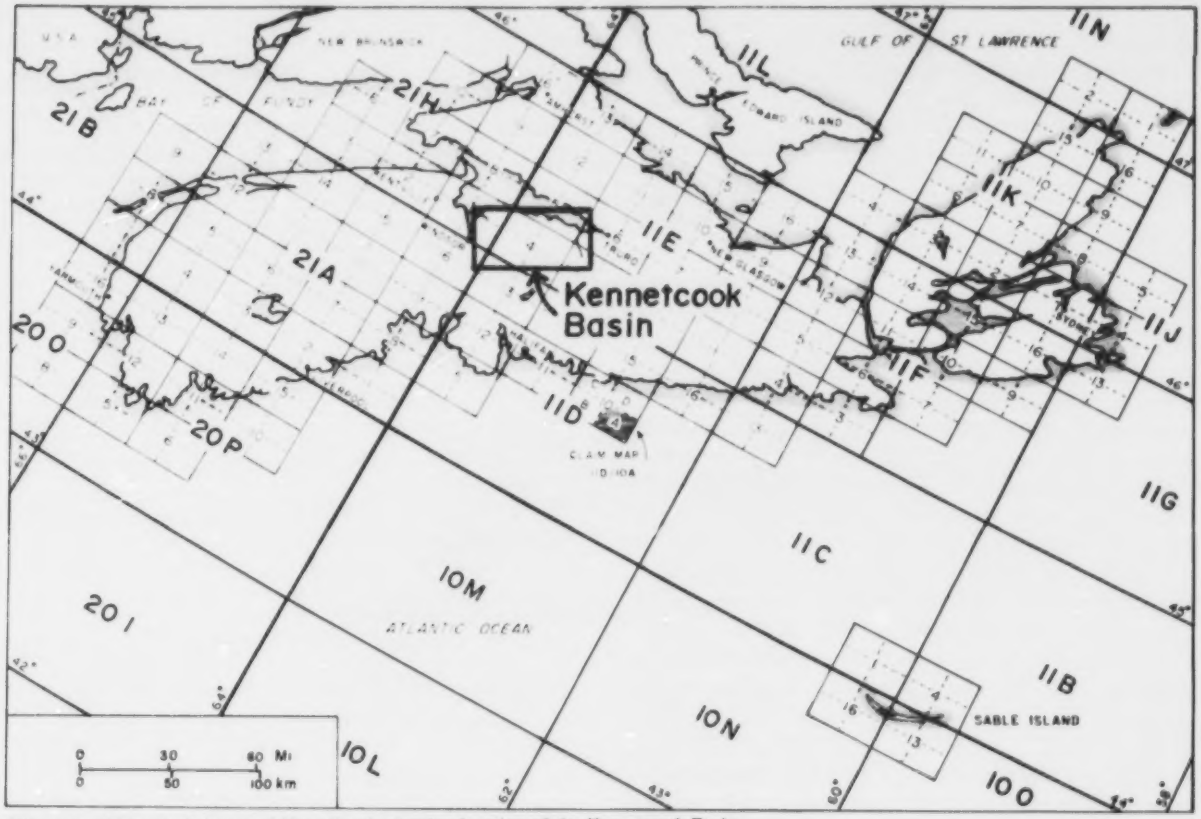

Figure 1. NTS map divisions of Nova Scotia showing location of the Kennetcook Basin.

Stellarton Graben, pull-apart basins were developed (Yeo and Ruixiang, 1987). In restraining bend or convergence areas, such as southern New Brunswick, there was basin inversion, overthrusting and penetrative deformation (Nance, 1987). Sedimentary environments ranged from coarse alluvial fans to transverse alluvial floodplain and lacustrine deposition. Rock units have been extensively disrupted by faulting and deformation throughout the late Carboniferous and early Permian and subsequently by early Mesozoic rifting.

Structurally, the north border of the Kennetcook Basin, including the Walton area, is extremely complicated, reflecting its proximity to the Cobequid - Chedabucto Fault System and the Fundy Rift. It is situated in the inferred transition zone where the northeast-trending structures of the Meguma Platform merge with the east-west fault system (both late Paleozoic dextral and Mesozoic sinistral). The Fundy Rift unfortunately onlaps the transition area, obscuring the geology.

As in the Shubenacadie Basin to the south, Carboniferous basin fill in the Kennetcook Basin is characterized by a major angular unconformity between locally deformed, lower to middle Carboniferous Windsor and Mabou (Canso) group rocks (late Viséan to early Namurian) and upper Carboniferous (late Westphalian B to early Westphalian C) strata of the Scotch Village Formation.

The evaporitic strata in the Kennetcook Basin are isoclinally and recumbantly folded into extremely complex structures along the south side as well as in the central part of the basin. Horton Group strata are also isoclinally to recumbantly folded along the north side of the basin. Scotch Village Formation rocks rest on an eroded surface which penetrates as deep as the base of the upper Windsor. These Scotch Village Formation rocks contain substantial amounts of recycled Windsor and Mabou group material. This unconformable relationship brackets the deformation event between the late Viséan to early Namurian (youngest

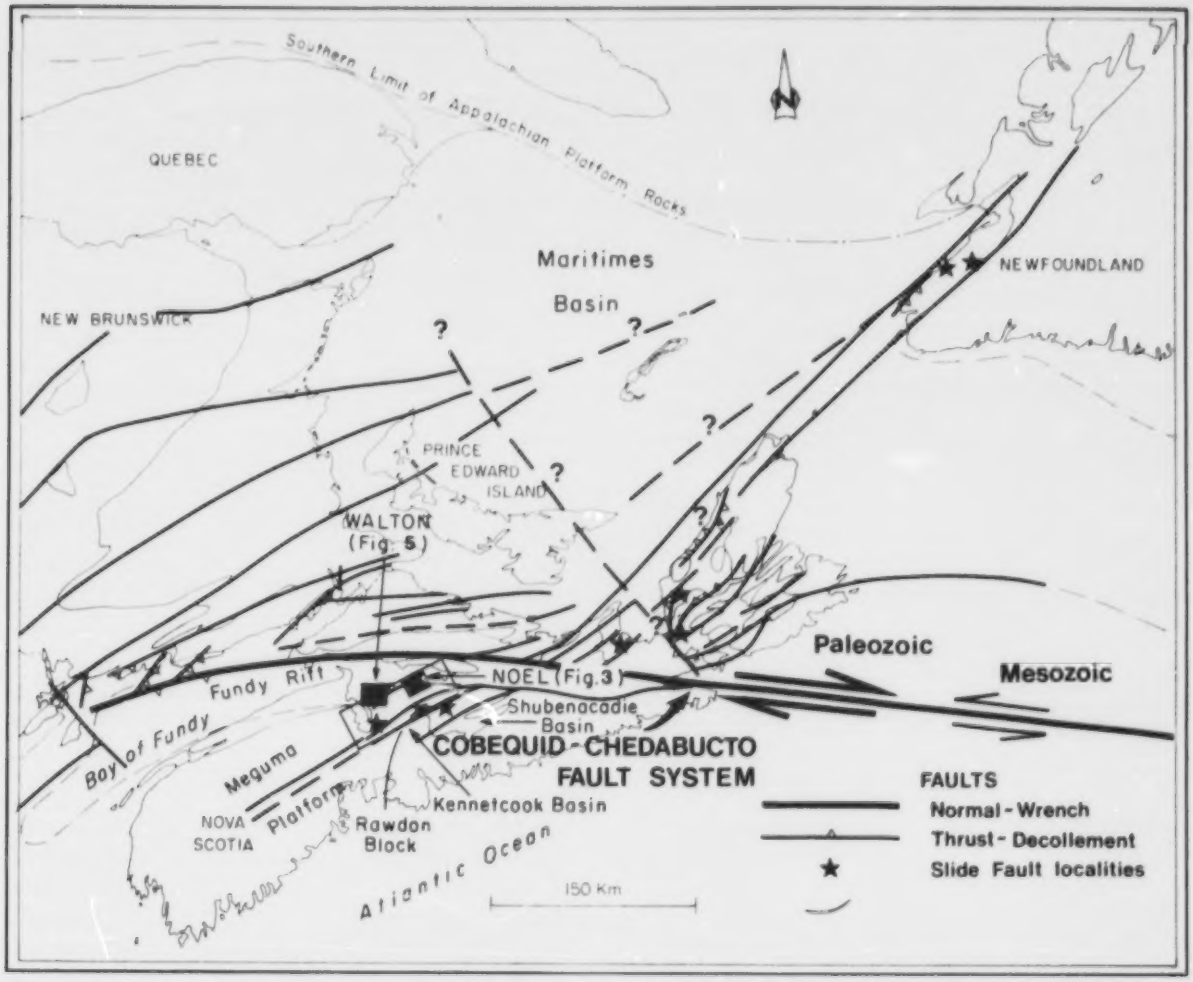

Figure 2. Regional location map illustrating dextral strike slip during the late Paleozoic and sinistral strike slip during the early Mesozoic.

deformed strata) and the oldest (late Westphalian B) strata above the unconformity. A Namurian to Westphalian B age is, therefore, the age range for deformation. This is comparable with the peak of tectonic activity in southern New Brunswick (Nance, 1987).

The strata intersected in drillhole RC85-1 near Kennetcook (Fig. 3), including the Scotch Village Formation, were tilted to near vertical and reverse-faulted, indicating movement after the Westphalian C on the Rawdon Fault to the south. This may represent a very late Carboniferous to Permian deformation event or conceivably might be linked to the Mesozoic rifting event.

SEISMIC INTERPRETATION, KENNETCOOK TO NOEL

Seismic lines 69Y and 73Y (Figs. 3 and 4) provide a previously unavailable view of the gross structure across the eastern part of the Kennetcook Basin. Like most onshore seismic data, the quality of these lines is not high. There are, however, sufficient drillholes to define several of the major rock unit boundaries, including the base of the Horton Group and the base of the Windsor Group in Soquip *et al.* Noel No. 1 (T.D. 1448 m). Conversions from two-way travel time on the seismic lines to depth are based on the following velocity estimates: from 0 to 0.5 seconds two-way travel time, 1800 m/sec, and from 0.5 to 1.0 seconds two-way travel time, 2500

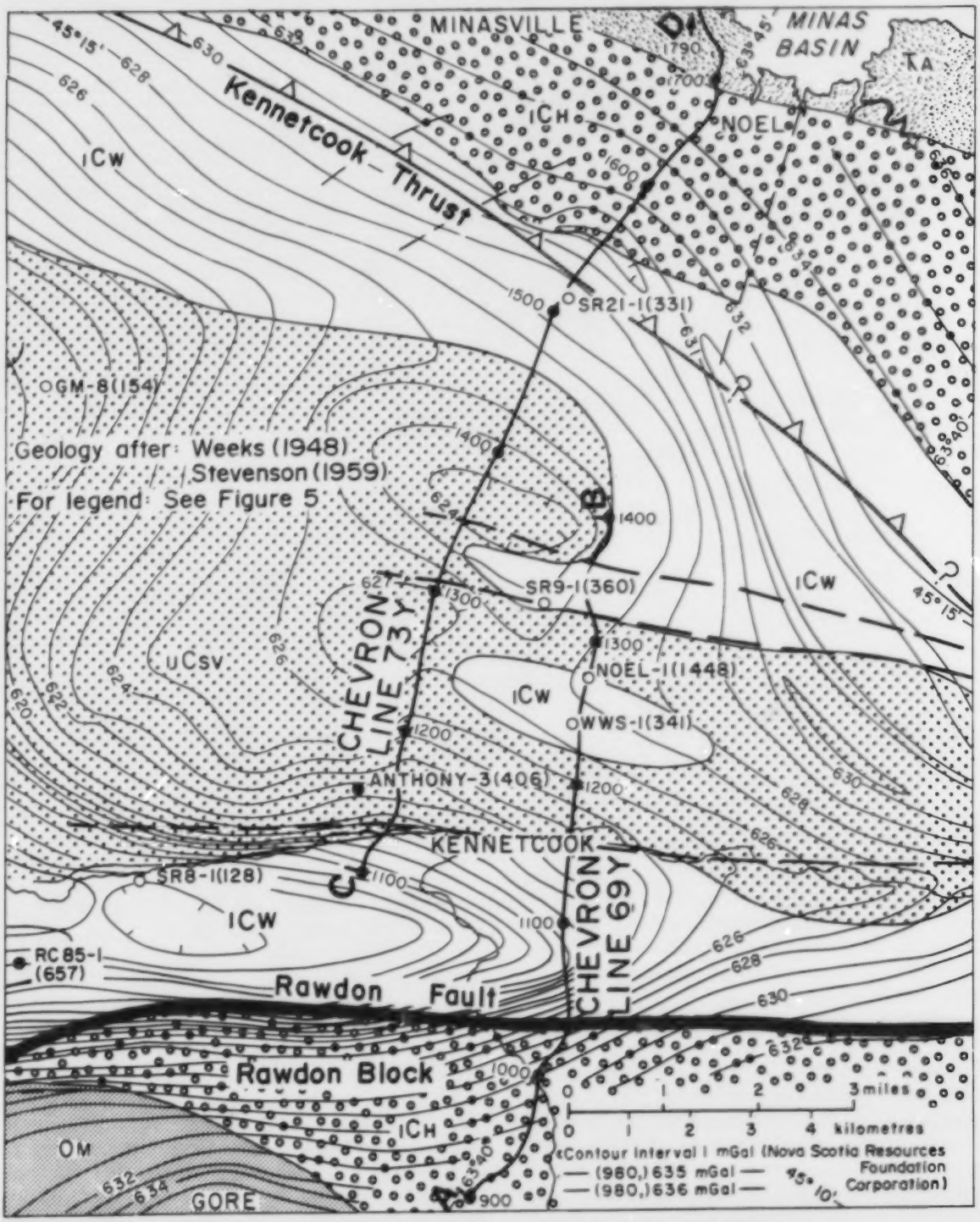

Figure 3. Geology and Bouguer gravity map of the eastern part of the Kennetcook Basin, for legend see Figure 5.

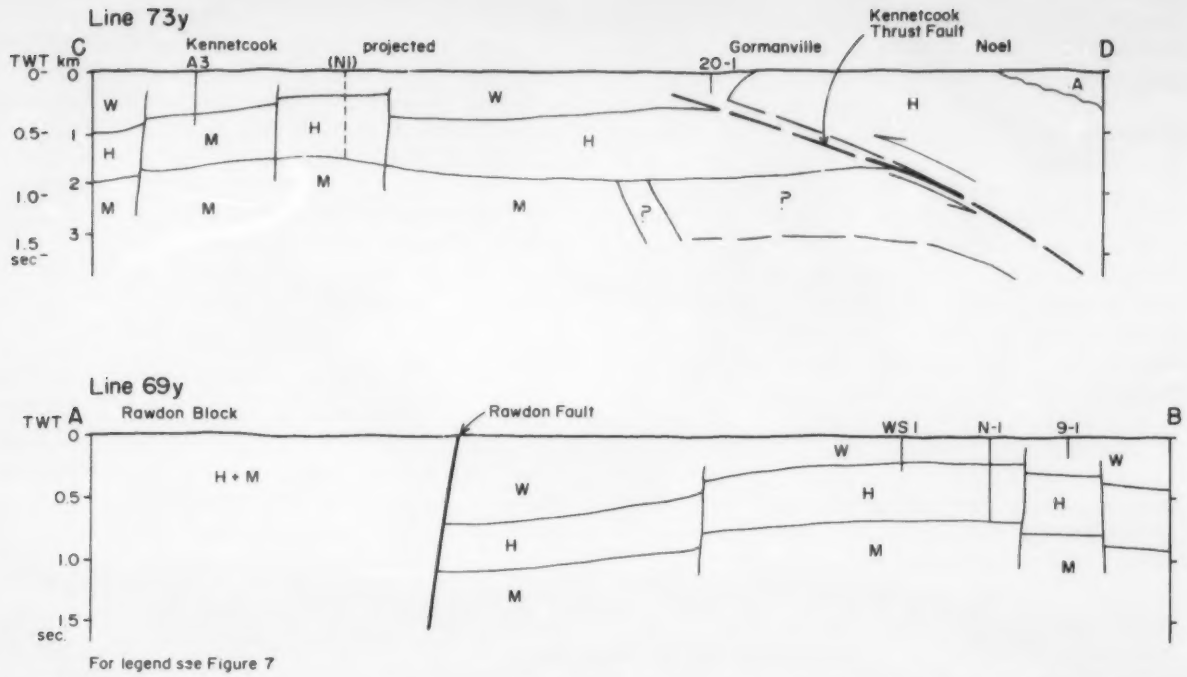

Figure 4. Interpreted cross-sections A-B and C-D derived from Chevron Exploration Limited lines 69Y and 73Y, Kennetcook to Noel, eastern part of Kennetcook Basin.

m/sec. These estimates are used for baseline purposes only and are probably underestimated in areas underlain by high velocity evaporites of the Windsor Group. Bouguer gravity data and modelling by Nova Scotia Research Foundation Corporation (1986) further define the general character of the basin in a line extending from near Gore, through drillhole RC85-1 (Fig. 3), to near Tennycape. This line is located approximately 10 km west of the seismic lines (73Y). The models on this line identify several important faults (analogous to those in the seismic interpretation) as well as the distribution of the low density, salt-dominated areas of the Windsor Group (e.g. near Kennetcook). The base of the Horton Group was indicated at a depth of approximately 3 to 4 km, deeper than in the shallower part of the basin in lines 69Y and 73Y.

The seismic lines indicate that the eastern part of the Kennetcook Basin has an unusual inverted geometry with a central arch and deeper faulted boundaries to the south and north. Two major fault sets with an ill-defined movement history occur in the area. The first is a steeply-dipping east-west set and the second is a steeply-dipping northeast-trending set. Thrust and slide faults are locally described or inferred to the east near the Shubenacadie River and to the south in the Shubenacadie Basin near its north border with the Rawdon Block.

Interpretation of the seismic lines is especially difficult at the ends, specifically near the contact with the Rawdon Block on the south and the Fundy Rift beneath Minas Basin to the north. Keppie (1982) indicated the northern contact as an overthrust on the Tectonic Map of Nova Scotia and identified it as the Kennetcook Thrust. This thrust fault structure is inferred to converge with the Cobequid - Chedabucto Fault System to the east where strike-slip motion dominates. The southern contact is interpreted to be a high angle reverse fault which continues to the northeast where it forms the complex, faulted northern boundary of the Shubenacadie Basin and eventually converges into the Cobequid - Chedabucto Fault System. Depth to basement (Meguma Group) at the south end of line 69Y (Fig. 3) is approximately 2300 m with up to 1200 m of salt-bearing Windsor Group strata. The central basin area shallows to 1400 m with approximately 350 m of Windsor Group rocks. It then deepens to at least 1800 m near the Horton - Windsor contact at Gormanville.

The pick on the base of the Horton Group is not clear in the area north of shotpoint 1450 on line 73Y. The strong reflectors extending to shotpoint 1650 are not well understood but conceivably represent a thick section of Horton Group strata. This reflective character is not typically associated with Meguma Group basement rocks. Another conjecture may be that these reflectors are from the Silurian to Devonian strata correlative with the Torbrook Formation and related units. The block of Horton Group strata between Gormanville and Noel Bay appears to be structurally separated from, and is interpreted to partially over-ride, the basin form of the Kennetcook Basin to the south. A low angle, northerly-dipping (calculated 20°) thrust fault is inferred with projection to a depth of 400 m near Gormanville and to 2400 m near Noel Bay. Dips in the Horton Group strata outcropping in the upper overthrust block range from 35° at Gormanville up to 60° at the Triassic unconformity. Weak reflectors occur locally within this block and indicate variable dips to the south.

Data degradation in the extreme north end of the section in line 73Y precludes delineating the exact limits of Meguma Group basement rocks and the contact with Horton Group strata. Unless there has been substantial structural thickening of the Horton (by folds or thrust faults) in the north end of the section, the estimated 1000 m of Horton Group strata identified in the basin cannot fill the space beneath the Windsor Group and Triassic strata (probably Wolfville and Blomidon formations) between shotpoints 1600 and 1775. A series of strong, gently-dipping reflectors is present in the area below 1.9 seconds and between shotpoints 1450 and 1700. These are inferred to be below the projection of the angular unconformity that constitutes the Horton - Meguma contact but are extremely unusual for basement reflectors. They alternatively may be an 'older section' of Horton Group rocks, bounded to the south by block faults near shotpoint 1450, or perhaps they are gently folded equivalents of the Torbrook Formation and younger strata.

Although these interpretations of the seismic data are not unique, they are consistent with the geology defined in the Shubenacadie Basin, particularly with the trend of increasingly complex structure in areas proximal to the Cobequid - Chedabucto Fault System. Major questions and problems include: (1) the northern limit of the Meguma Group and the possible occurrence of younger basement rocks (possibly Torbrook Formation) near Noel, (2) the nature, thickness and paleogeographic relationship of the Horton Group strata inferred to extend beneath Triassic rocks, (3) the kinematics of the thrust fault inferred to be present along the north and northwest border of the basin (i.e. is it a complex strike-slip or dip-slip fault, transitional into a thrust fault?) and (4) the precise nature of the Rawdon Fault (is it part of the Tobeatic Fault Zone?) which has up to 2300 m apparent dip-slip; is it a high angle reverse fault, a northward overthrust or simply the strike-slip juxtaposition of a basin and horst? If the complex recumbent and isoclinal deformation in the Windsor Group extends across the Kennetcook Basin and south into the Shubenacadie Basin and is related to a major thrust and compression event along the Cobequid - Chedabucto Fault System, then the Rawdon Block must be a later feature, possibly developed after late Carboniferous uplift.

SEISMIC INTERPRETATION, WALTON AREA

Seismic lines are unfortunately not available for the area west of Chevron lines 69Y and 73Y; however, the geology interpreted in the Noel - Kennetcook area may reasonably be projected into the Walton area. Similar high angle faults were modelled by the Nova Scotia Research Foundation Corporation in a line through drillhole RC85-1 to Tennycape. The highly faulted and locally intensely deformed Walton Belt, described by Boyle (1972) and Fyson (1967), extends along the northwest border of the Kennetcook Basin from the Avon River northeast to Walton (Fig. 5). The belt then continues in an easterly direction to the Shubenacadie River. In a dextral strike-slip or transpressive setting the re-orientation from east-west to northeast-southwest would produce a restraining bend or convergence environment prone to complex deformation and thrusting.

The local geology mapped by Crosby (1962) and Boyle (1972), including the detailed geology of the Walton Mine, together with scattered drill data and the gross Bouguer gravity patterns, generally support the continuity of the inferred Kennetcook Thrust along the northwest border of the Kennetcook Basin. Boyle (1972) reported two

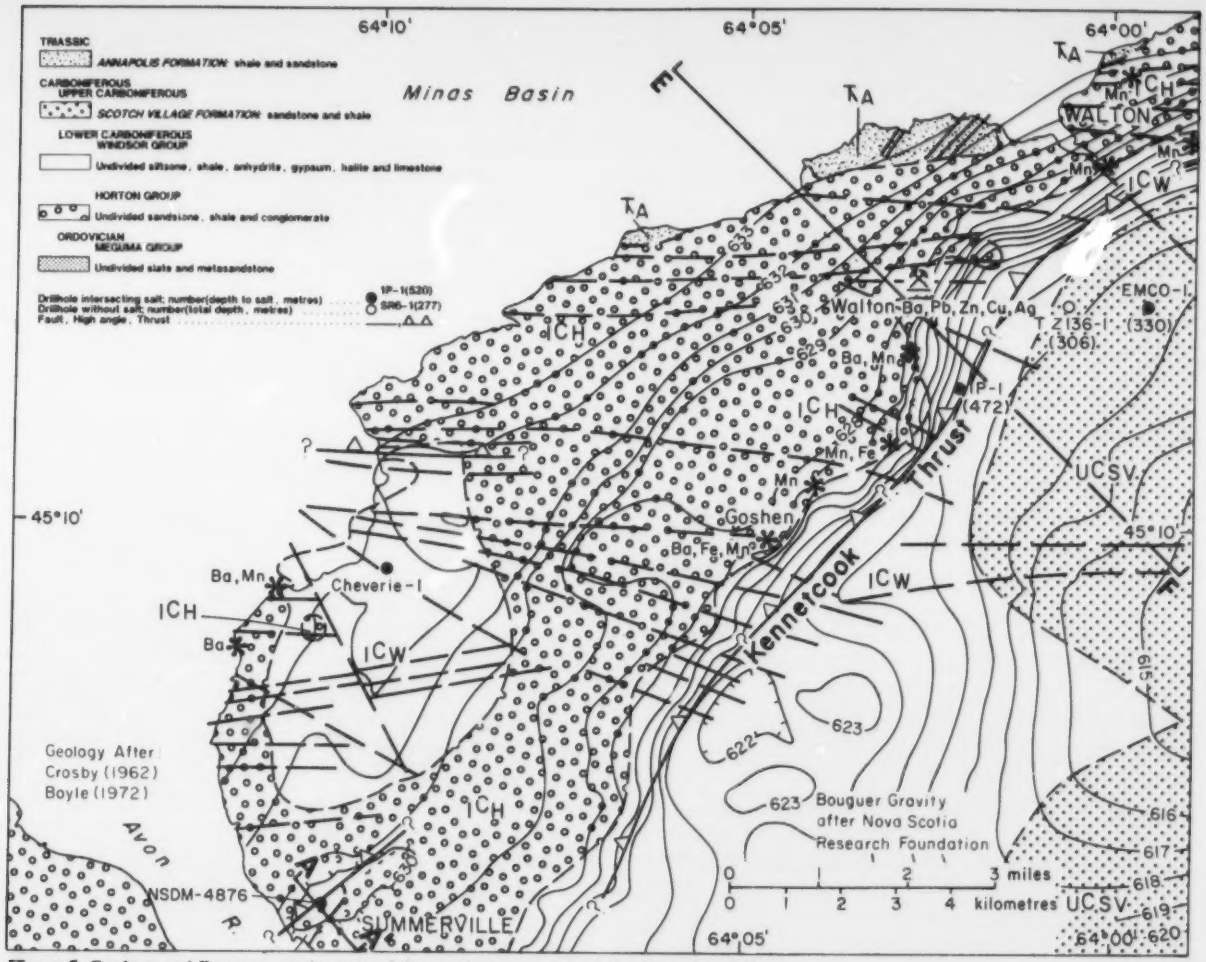

Figure 5. Geology and Bouguer gravity map of the northwestern part of the Kennetcook Basin.

major fault sets with a multiple movement history: (1) a steeply-dipping east-west set with commonly associated mineralization and (2) a steeply-dipping northwest-trending set. Thrust faults are locally described or inferred, as is a minor set of northeast-trending faults. Thrust faults indicative of some component of compression (shortening) were reported near Cheverie, Johnsons Cove, Summerville and Whale Cove (Walton) by Crosby (1962) and Boyle (1972).

The Walton deposit (Fig. 6) is a complexly deformed, pipe-shaped body of barite with a silver-rich, base metal sulphide zone extending down-dip and laterally. The geology of the deposit has been described in detail by Boyle (1972) and Patterson (1988). The deposit is hosted by sideritized carbonate (Macumber Formation and related Pembroke breccia) and siliciclastics at the Horton - Windsor contact. The contact in the mine area is highly disrupted and typically steeply-dipping. Boyle (1972) favoured a replacement origin for the deposit and suggested that it formed in the tectonically active late Carboniferous or perhaps as late as the Mesozoic.

Mineral exploration drilling to depths of up to 500 m and gravity surveys along the edge of the basin in this area indicate the presence of thick evaporites, including salt and anhydrite. The Windsor Group strata are structurally complex and dip steeply near the contact and are further disrupted by collapse related to the subsurface dissolution of evaporites (salt and anhydrite). Diamond-drill hole S-88-2 (Fig. 6) was drilled by Gunnar Gold Inc. to test the continuity and

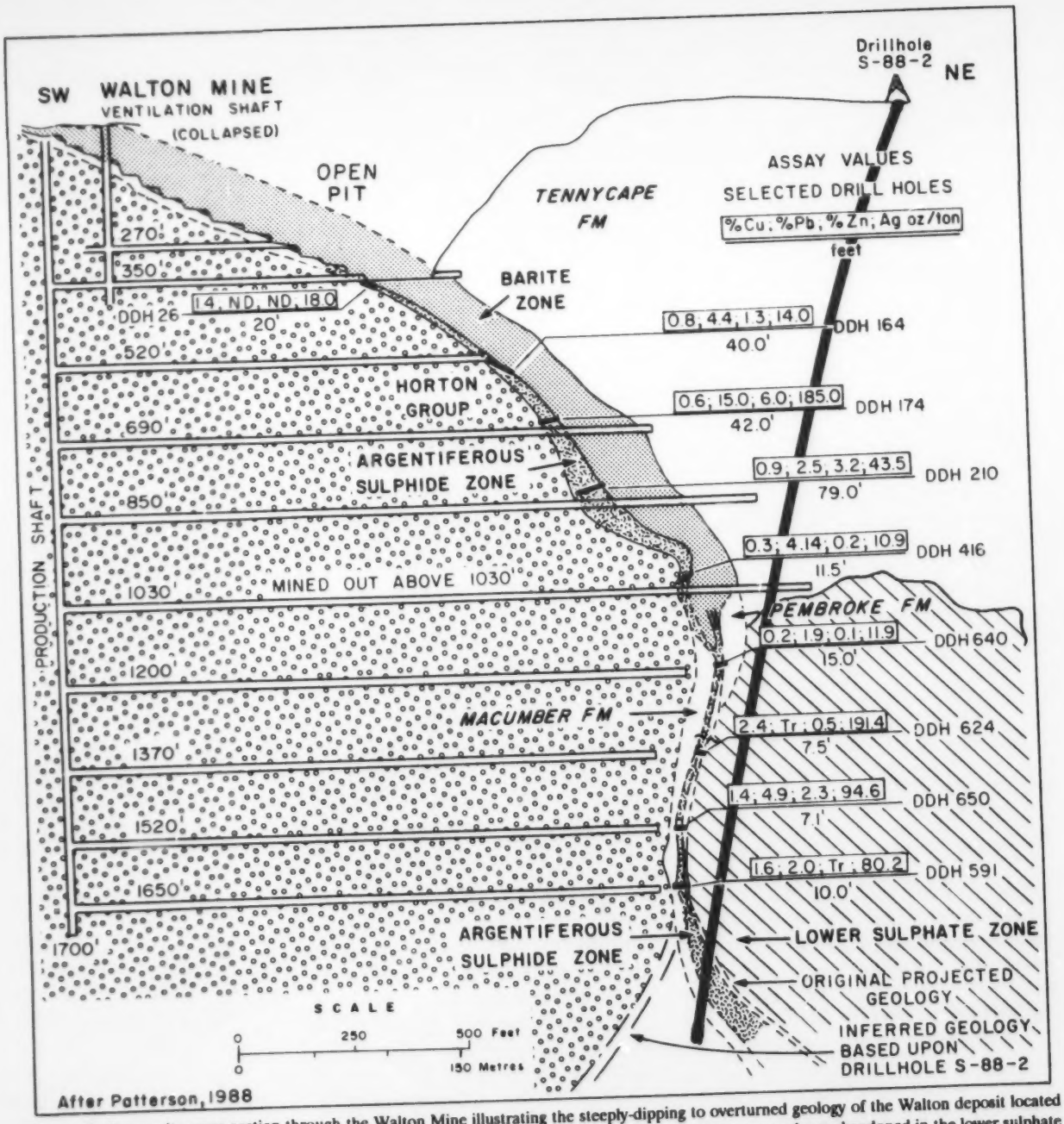

Figure 6. Composite cross-section through the Walton Mine illustrating the steeply-dipping to overturned geology of the Walton deposit located at the Horton - Windsor contact. Note drillhole S-88-2 did not intersect the argentiferous sulphide zone and was abandoned in the lower sulphate (basal anhydrite) of the Windsor Group.

orientation of the down-dip extension, probably dipping to the south of the argentiferous sulphide zone at the Walton deposit. The drillhole intersected the projected area where a south-dipping zone should occur; however, the hole was abandoned in the basal anhydrite of the Windsor Group at a depth of 670.5 m. The dip of the contact in this area is vertical to overturned to the north or northwest. This makes a steep overfold and overthrust a highly plausible interpretation.

Isoclinal and recumbent folds are present in the

Windsor Group in the Walton area and near Windsor. The Walton Mine is located near the transition area from the east-west Cobequid - Chedabucto Fault System to the subsidiary northeast trend. This generally places the area in a zone prone to thrusting. The continuation of the Kennetcook Thrust from the Noel area into the Walton area to the west also allows a relatively simple explanation of why the extensive faults in the Horton and younger strata in the Walton Belt do not apparently extend into the Kennetcook Basin (Figs. 5 and 7). This may be attributed to their confinement within the relatively competent overthrust block. Northeast faults dominate the basin areas to the south but are rare in the Walton Belt. This absence may also be attributed to the overthrust geology. The overthrust is an appealing cause of the extensive and complex recumbent and isoclinal folding in the salt-dominated part of the Windsor Group above the basal anhydrite and Macumber Formation (basal limestone).

This decollement zone has been described by Boehner (in press) in other Carboniferous basins, including the Shubenacadie Basin to the south; thus, the Kennetcook Thrust may extend from the Kennetcook Basin to the Shubenacadie Basin. If this complex, deformed zone continues across the Kennetcook Basin to include similar sections in the Windsor and Kennetcook areas then there must have been substantial (kilometres) tectonic shortening of the middle Viséan strata.

SUMMARY AND CONCLUSIONS

The occurrence of thrust faults with a range of magnitudes and associations has been reported at various localities in Carboniferous basins, including the Kennetcook Basin area adjacent to the Cobequid - Chedabucto Fault System and the Fundy Rift. Although the inferred relationship between tectonics and metallogenesis in the basins is controversial, it would be important both for the genesis of mineral deposits and their subsequent disruption.

The structural geology of the Kennetcook Basin is complex and appears to be compatible with restraining and/or convergence tectonics on subsidiary faults related to dextral east-west strike-slip motion on the Cobequid - Chedabucto Fault System. Superposition of the Fundy Rift in a later extensional environment (Mesozoic) has further complicated the interpretation of the structural history. Evidence for overthrusting has previously been restricted to small-scale thrust fault occurrences (tens to hundreds of metres offset) reported near the western extremity of the Basin. The concept that these scattered localities are indicators or small components of a larger thrust structure or system (potentially thousands of metres offset) is very attractive. A genetic relationship with similar complex structures identified near Windsor, Kennetcook, and along the north border of the Shubenacadie Basin is similarly appealing. The overall transpressive-thrusting model is compatible with localized gravity slide tectonics. The Windsor Group evaporites in general and the lowermost Windsor Group salt section, stratigraphically above the relatively competent basal anhydrite, in particular are a preferred locus for ductile deformation and decollement in the Carboniferous basin fill.

Reflection seismic survey lines across the basin near Kennetcook and Noel, together with deep and shallow exploration drillholes, permit definition of the gross basin configuration. Interpretation of large-scale features of the seismic lines indicates the southeast border of the basin is a major high angle fault (2300 m dip-slip) and the north border appears to be a southward overthrust (Kennetcook Thrust) of deformed Horton Group and basal Windsor Group strata (together with numerous mineral occurrences). The concept that post-mineralization overthrusting (during the Namurian to Westphalian B or perhaps later) along the Walton Belt in the northwest border of the basin may have concealed significant Cu-Pb-Zn-Ag-Ba deposits is intriguing. Exploration strategies and techniques in this environment would necessarily be indirect, innovative and expensive, perhaps including high resolution seismic surveys. Depth, exploration expense and historical mining problems are obvious major challenges.

REFERENCES

Bell, W. A. 1929: Horton-Windsor District, Nova Scotia; Geological Survey of Canada, Memoir 155, 268 p.

Bell, W. A. 1958: Possibilities for the occurrence of petroleum reservoirs in Nova Scotia; Nova Scotia

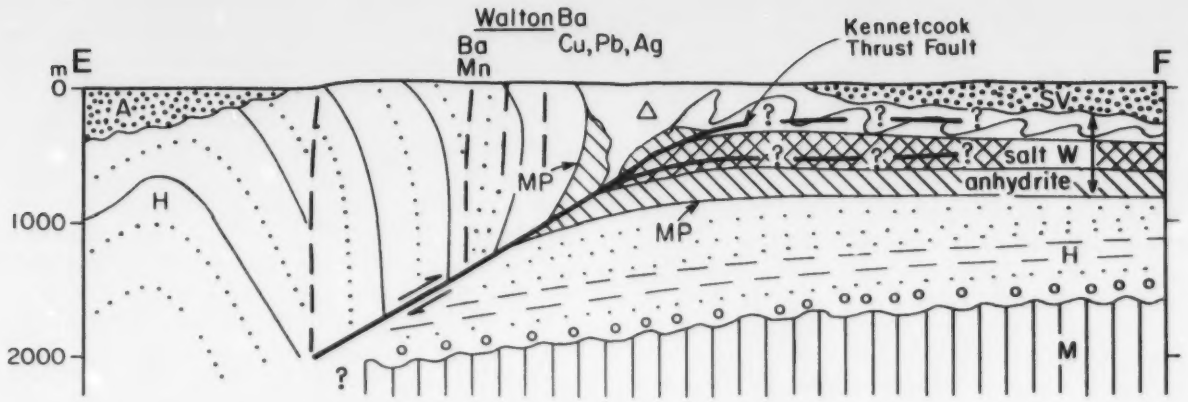

Figure 7. Geological cross-section E-F through the Walton Mine area illustrating the interpreted Kennetcook Thrust and its relationship with the Kennetcook Basin. Deep geology extrapolated from seismic section 73Y. A = Annapolis Formation, H = Horton Group, MP = Macumber and Pembroke formations, M = Meguma Group, SV = Scotch Village Formation, W = Windsor and locally Mabou Group.

Department of Mines Report, p. 177.

Boehner, R. C. in press: The role of evaporites in the structural development of Carboniferous basins in Nova Scotia: an overview; Atlantic Geology special issue on Late Paleozoic Basins in Atlantic Canada.

Boehner, R. C. and Ryan, R. J. 1990: Economic geology of late Paleozoic-early Mesozoic basins in Nova Scotia: mid-Westphalian tectonism and metallogenesis; *in* Mines and Minerals Branch, Report of Activities 1989, Part A, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Mines and Energy, Report 89-3, p. 103-108.

Boyle, R. W. 1972: The geology, geochemistry, and origin of the barite, manganese, and lead-zinc- copper-silver deposits of the Walton - Cheverie area, Nova Scotia; Geological Survey of Canada, Bulletin 166, 181 p.

Crosby, D. G. 1962: Wolfville map area, Nova Scotia (21H/1); Geological Survey of Canada, Memoir 325, 67 p.

Fyson, W. K. 1967: Gravity sliding and cross folding in Carboniferous rocks, Nova Scotia; American Journal of Science, v. 265, p. 1-11.

Keppie, J. D., 1982: Tectonic Map of the Province of Nova Scotia; Nova Scotia Department of Mines and Energy, scale 1:500 000.

Nance, R. D. 1987: Dextral transpression and late Carboniferous sedimentation in the Fundy coastal zone of southern New Brunswick; *in* Sedimentary Basins and Basin Forming Mechanisms, eds. C. Beaumont and A. J. Tankard; Canadian Society of Petroleum Geologists, Memoir 12, and Atlantic Geoscience Society, Special Publication 5, p. 363-377.

Nova Scotia Research Foundation Corporation 1986: Interpretation of a gravity profile across the Windsor - Kennetcook area of the Minas Sub-basin of Nova Scotia; unpublished report by Nova Scotia Research Foundation Corporation for the Nova Scotia Department of Mines and Energy, July 1986, 15 p.

Patterson, J. M. 1988: Exploration potential for argentiferous base metals at the Walton deposit, Hants County, Nova Scotia; *in* Mines and Minerals Branch, Report of Activities 1987, Part B, eds. D. R. MacDonald and Y. Brown; Nova Scotia Department of Mines and Energy, Report 88-1, p. 129-134.

Smith, L. and Collins, J. A. 1985: Unconformities, sedimentary copper mineral-ization, and thrust faulting in the Horton and Windsor Groups, Cape Breton Island and central Nova Scotia; Ninth International Congress on Carboniferous Stratigraphy and Geology, Compte Rendu, v. 3, p. 105-116.

Stevenson, I. M. 1959: Shubenacadie and Kennetcook map areas, Colchester, Hants and Halifax

Counties, Nova Scotia; Geological Survey of Canada, Memoir 302.

Weeks, L. J. 1948: Londonderry and Bass River map areas, Colchester and Hants Counties, Nova Scotia; Geological Survey of Canada, Memoir 245, 86 p.

Yeo, G. M. and Ruixiang, G. 1987: Stellarton Graben: an Upper Carboniferous pull-apart basin in northern Nova Scotia; *in* Basins and Basin Forming Mechanisms, eds. C. Beaumont and A. J. Tankard; Canadian Society of Petroleum Geologists, Memoir 12, and Atlantic Geoscience Society, Special Publication 5, p. 299-309.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 49-60

VARIATION IN THE MAFIC MINERAL CONTENT OF THE SCRAG LAKE PLUTON, SOUTH MOUNTAIN BATHOLITH: EVIDENCE FOR A ZONED PLUTON[1]

R. J. Horne, M. C. Corey, L. J. Ham and M. A. MacDonald

INTRODUCTION

The Scrag Lake pluton (Fig. 1) is one of the many plutonic centres of the South Mountain Batholith, southwestern Nova Scotia. Geological mapping (1:50 000 scale) of the South Mountain Batholith was carried out by the authors from 1985-1989 and the results are summarized in Figure 2a. Mapping methodology involved division of the granitoid rocks into mappable units (map units) based essentially on modal mineralogy (quartz-feldspars-micas), texture and field relationships. Compositional and textural similarity among map units allowed for a natural grouping of map units into seven lithologic types (shown in Fig. 2a), which include granodiorite, biotite monzogranite, muscovite-biotite monzogranite, coarse grained leucomonzogranite, fine grained leucomonzogranite, leucogranite and mafic porphyry. The reader is referred to MacDonald *et al.* (1989) for a

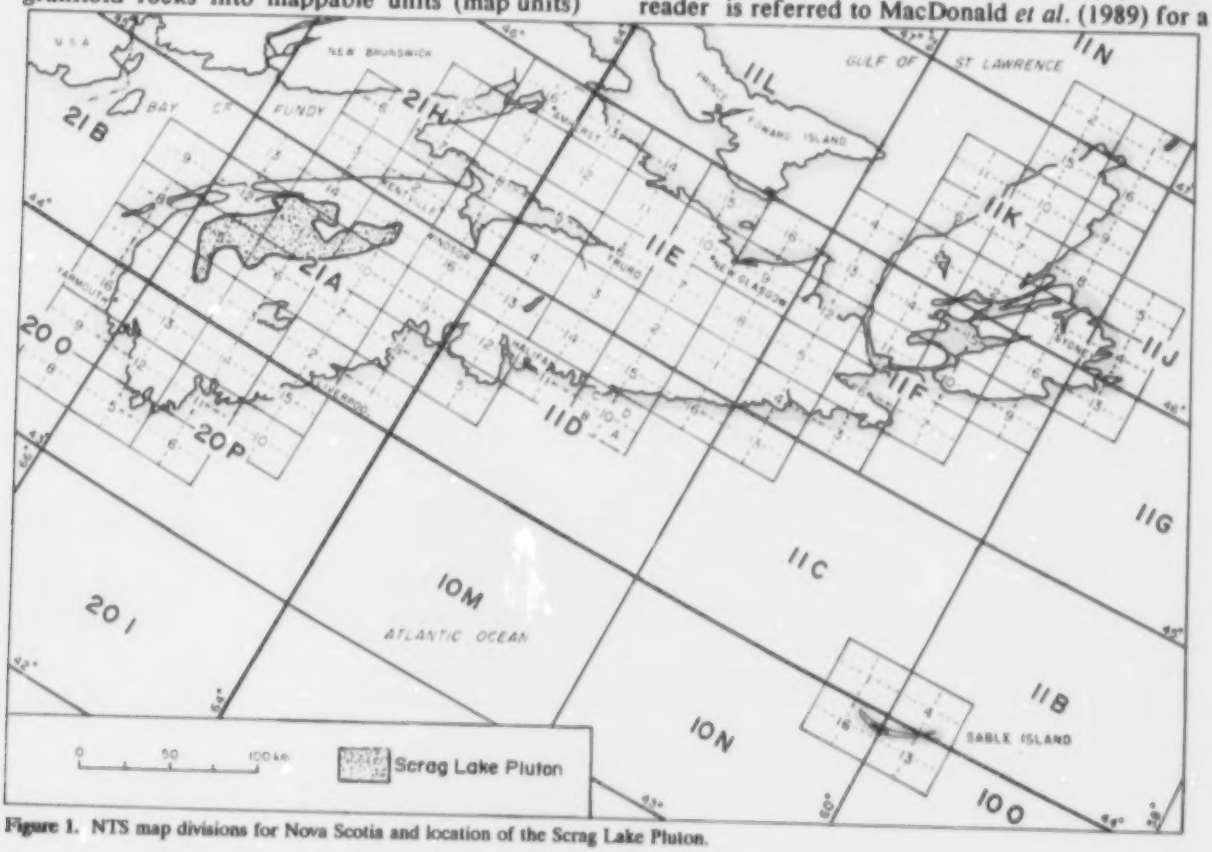

Figure 1. NTS map divisions for Nova Scotia and location of the Scrag Lake Pluton.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Mineral Development Agreement (1984-1989)

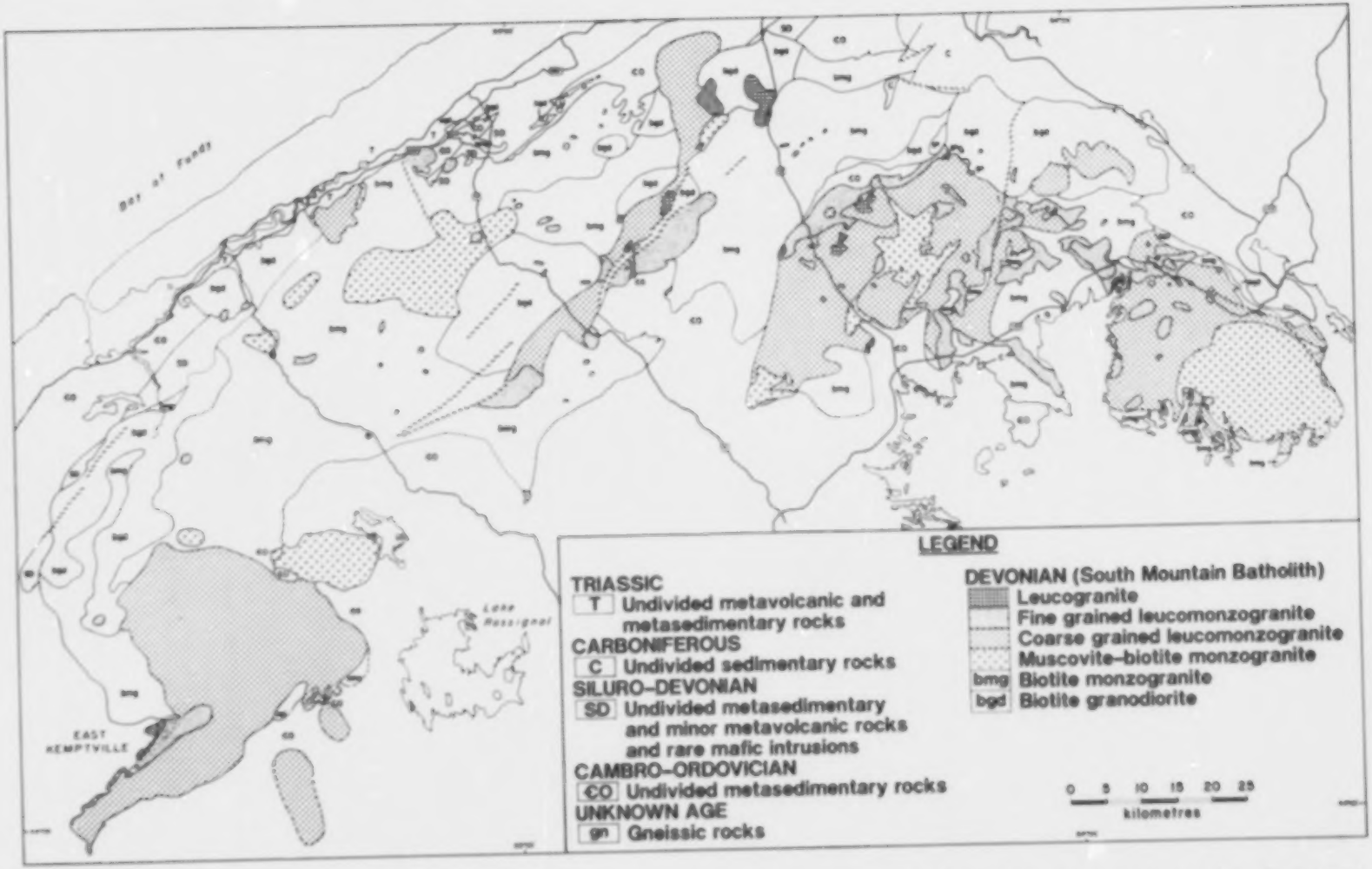

Figure 2a. Simplified geological map of the South Mountain Batholith showing distribution of the various rock types (modified from MacDonald et al., 1989). Note that mafic porphyry is a seventh rock type in the South Mountain Batholith, but its exposure is too restricted to be seen on a map of this scale.

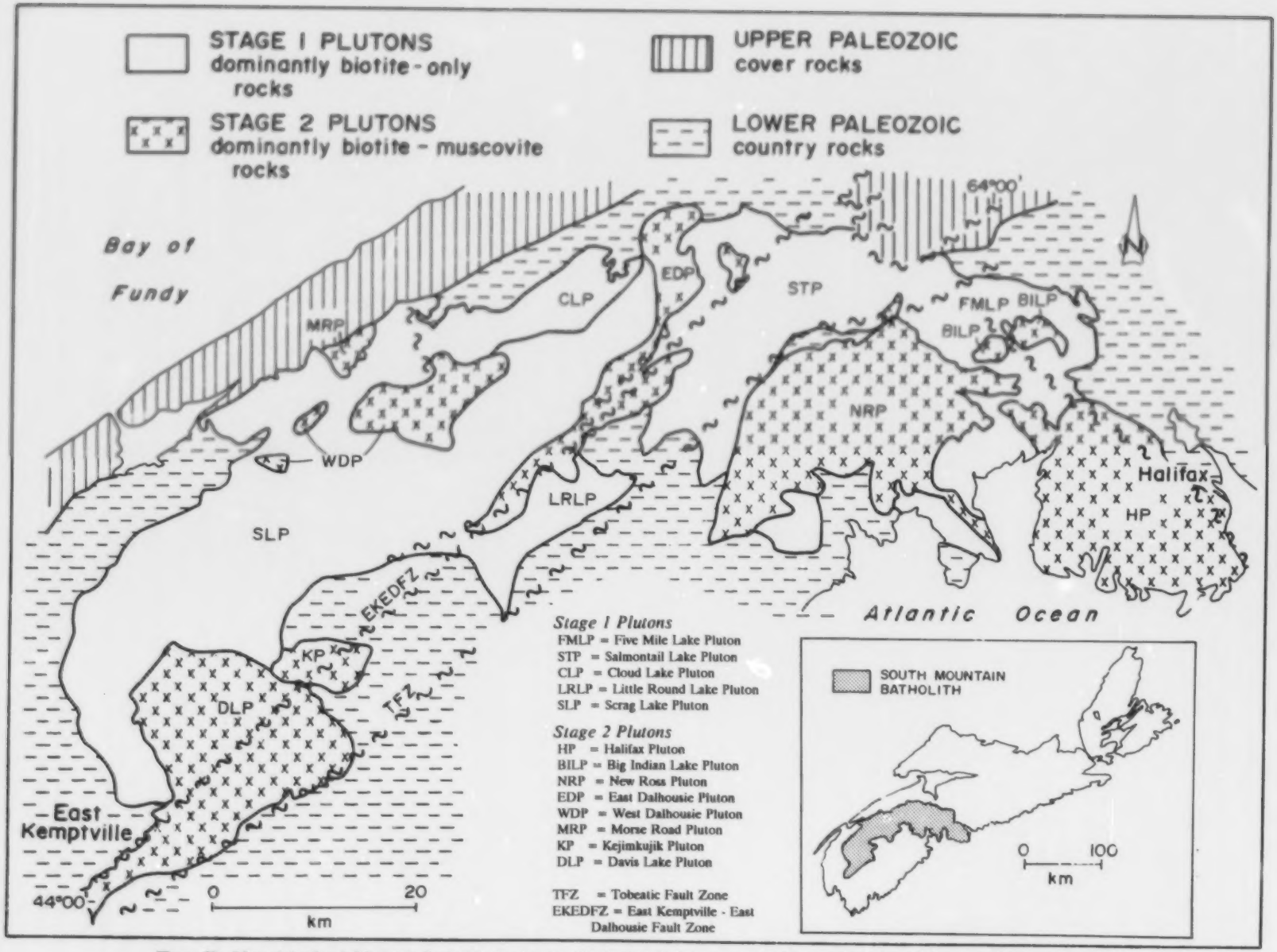

Figure 2b. Map of the South Mountain Batholith showing the distribution of plutons; see text for an explanation of Stage 1 and Stage 2 plutons.

full description of these rock types; note that the intrusive suite is no longer used as a rock type.

Thirteen plutons have been recognized in the South Mountain Batholith (MacDonald *et al.*, 1990; Fig. 2b); they vary in character from composite and zoned to singular and uniform intrusions. Pluton boundaries are delineated by regional cross-cutting relationships as defined by lithologic and chemical zonation. These plutons naturally group into two types on the basis of lithology: (1) those dominated by muscovite- and biotite-bearing rock types (muscovite-biotite monzogranite, fine- and coarse-grained leucomonzogranite and leucogranite) and (2) those dominated by biotite-bearing rock types (biotite monzogranite and granodiorite); compare Figure 2a and Figure 2b. Although the intrusive history of the batholith is complex and the sequence of pluton intrusion is unknown, plutons dominated by muscovite- and biotite-bearing rock types invariably intrude those dominated by biotite-bearing rock types. Thus, in a relative sense, the plutons dominated by biotite-bearing rock types can be referred to as Stage 1 plutons and those dominated by muscovite- and biotite-bearing rock types as Stage 2 plutons (Fig. 2b). Recent geochronological studies (Chatterjee and Ham, 1991; Harper, 1988; M. A. MacDonald, personal communication, 1990) indicate that all phases of the South Mountain Batholith were intruded at roughly the same time (ca. 370 Ma).

Petrographic and/or chemical variation is displayed by several of the plutons within the batholith and is an inherent feature of most intrusive rocks, resulting from fractional crystallization processes. Within the South Mountain Batholith, a geological explanation is apparent for interplutonic petrographic variation in plutons with a wide range of lithologies. For example, variation in the composite Halifax and New Ross plutons is related to lithologic zonation (Fig. 2a; MacDonald and Horne, 1988; Corey, 1987). A geological explanation for internal petrographic and chemical variation is less obvious for plutons of restricted lithologic-chemical range where the variation is too subtle to be mapped in the field. However, detailed petrographic and chemical studies have revealed that systematic petrographic and chemical variation (zoning) exists within lithologically restricted plutons (Horne *et al.*, 1989; Chatterjee and Horne, 1991) such as the Five Mile Lake, Salmontail Lake and Davis Lake plutons (Fig. 2b). The purpose of this paper is to evaluate petrographic variation within the Scrag Lake pluton based on modal determination of mafic mineral phases from point counting.

GEOLOGY OF THE SCRAG LAKE PLUTON

The Scrag Lake pluton is the largest pluton in the South Mountain Batholith with an exposed area of approximately 2457 km^2 (Fig. 2b). This pluton is a Stage 1 pluton and is intruded by several Stage 2 plutons, namely the Davis Lake, West Dalhousie, Morris Road, Kejimkujik and East Dalhousie plutons (Fig. 2b). Biotite monzogranite (78.7%) and granodiorite (21.3%) are the dominant rock types that constitute the Scrag Lake pluton (at the present level of exposure); however, several small leucomonzogranite bodies which intrude the Scrag Lake pluton (Fig. 2a) may be genetically related. Quartz, K-feldspar, plagioclase and biotite are the major mineral constituents of the rocks of the Scrag Lake pluton, with minor amounts of cordierite and chlorite. Texturally, the rocks are predominantly medium- to coarse-grained and megacrystic (Fig. 3), but local areas display a fine- to medium-grained porphyritic texture.

As in other areas of the South Mountain Batholith dominated by granodiorite and biotite monzogranite (i.e. Stage 1 plutons), the limited petrographic range and overall similar appearance of these rocks make lithologic subdivision or recognition of systematic mineralogical variation difficult in the field. In an attempt to assess lithologic variation within the Scrag Lake pluton, which was unrecognized in the field, and to resolve potential bias resulting from individual mapping, all slabs from this pluton were arranged in relative (geographic) position (Fig. 4). However, except for areas underlain by fine- to medium-grained porphyry, no apparent variation could be identified. To comprehend the difficulty of visually assessing the petrographic variation of slabs from the Scrag Lake pluton the reader is referred to Figure 3, which, as discussed below, displays most of the petrographic variation observed in this pluton.

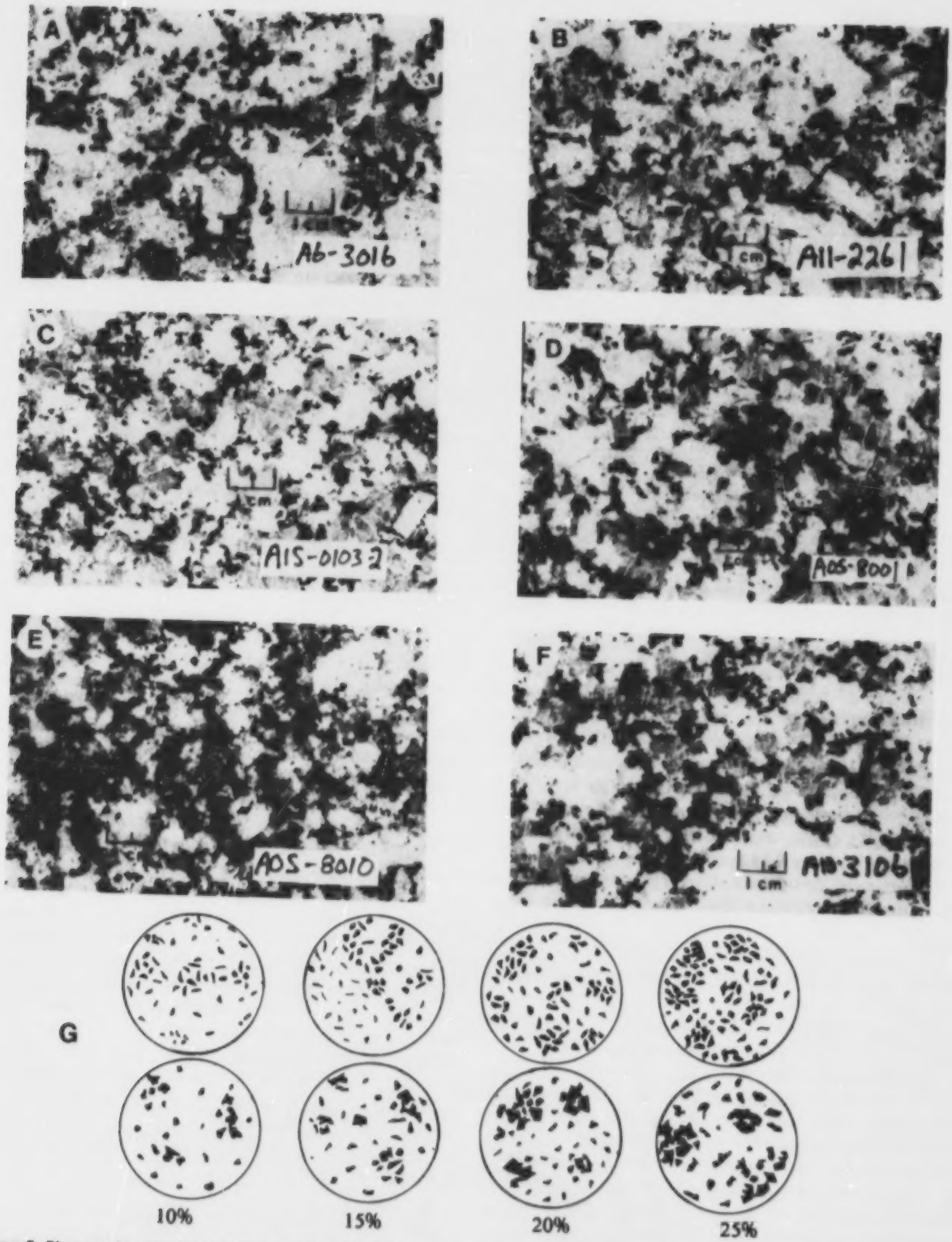

Figure 3. Photograph of selected slabs from the Scrag Lake pluton showing modal per cent mafic mineral content as determined by point counting of (a) 13.0%, (b) 15.6%, (c) 16.4%, (d) 17.1%, (e) 18.2%, (f) 20% and (g) a graphic representation of known percentages of mafic minerals.

Figure 4. Photograph showing the arrangement of slabs from the western portion of the South Mountain Batholith in relative geographic position. Grid lines represent boundaries of the NTS map sheet indicated (compare with Fig. 5).

POINT COUNTING

Methodology

Rock specimens were systematically collected during geological mapping in order to reflect noticeable lithologic change or to establish a reasonable sampling density, the latter restricted by outcrop density. The specimens are considered representative of the outcrop (or area) and generally range between 10-20 cm in diameter.

Specimens were cut into slabs, averaging ≈100 cm^2 in area, and stained for K-feldspar on one side and coated with clear plastic on the opposite surface to help facilitate distinction of mafic phases. Modal analysis of mafic minerals was accomplished by placing a clear plastic grid with equally spaced points on the unstained side of the slab and counting the number of points intersecting a mafic mineral in a determined area. No distinction of the different mafic minerals (biotite, cordierite and chlorite) was made due to the difficulty in distinguishing them in cut slabs. A common grid with a 3 mm spacing between points was used for all samples and an attempt was made to count an area of 81 cm^2 (900 points), although this was limited by the size of the slab.

The application of point counting data in evaluating petrographic variation is obviously dependent on the reliability of the point counting results. This reliability is affected by two factors: (1) how representative the sample is and (2) the meaningfulness (accuracy) of the point counting results. The former is a subjective value and difficult to quantitatively evaluate. A measure of the reliability of point counting, however, can be quantitatively evaluated. The principle sources of error in modal analysis by point counting include: (1) operator error (misidentification of grains, bias due to points falling on grain boundaries); (2) counting error (not counting enough points or counting over too small an area); and (3) sampling error (basing volumetric proportions from area analysis) (Solomon, 1963). Operator error is subject to individual expertise and the degree of difficulty in mineral identification and is considered insignificant in this study due to the relative ease of distinguishing mafic minerals.

Solomon (1963) presents a measure of the error reflecting counting and sampling error in point

counting in terms of the theoretical variance (V), represented by $44\ p\ s^3/RA\ [1 + 5.8(R/s)^3]$; where p is the modal percentage of the phase, s is the grid spacing, R is the average diameter of the phase and A is the area of the grid. The lower the value of V the more reliable are the data; Solomon (1963) recommends that values less than or equal to 2 be achieved. Although this formula is commonly applied to determine the parameters of grid spacing and area to achieve a desired variance for a phase of a particular average diameter and estimated per cent, here the formula was applied to evaluate the measure of error in determined modal analysis. The theoretical variance for each of the determined modal analyses was calculated (Table 1) using the per cent of mafic minerals determined by point counting, a common grid spacing of 3 mm, the calculated area based on the number of points counted, and an average grain size of 2 mm.

The parameters of area and grid spacing were predetermined for the sake of expediency and thus the only real variables affecting the value of the theoretical variance for these samples are per cent mafic minerals and grain size. The effect on the value of V produced by varying the value of per cent is indicated in test samples 1-7, Table 1, which show that, all else remaining equal, the value of V increases with increasing per cent of mafic minerals. As mentioned above, an estimated average grain diameter of 2 mm was applied in the calculation of V for all samples. This was mainly due to the impracticality of accurately determining the average grain diameter, considering the inhomogeneity of grain size and the irregularity of grain shapes (see Fig. 3). The effect on the value of V produced solely by varying the value of grain diameter from 1 mm to 2 mm to 3 mm (a range of 1-3 mm is considered to account for the potential range of average grain diameter for samples considered here) is indicated by test samples 7, 8 and 9, respectively, Table 1.

Results

Modal analysis of the mafic mineral content by point counting was done for 124 slabs from the Scrag Lake pluton. The results for each sample, along with the number of points counted, area counted and the calculated variance, are presented in Table 1 and sample locations are shown in Figure 5. The results indicate that the modal per cent of mafic minerals in the Scrag Lake pluton ranges between 9.7% and 24.6%, with the majority, 87 of 124 samples (70%), ranging from 14%-20%.

As indicated above, a quantitative measure of the reliability of point counting data is reflected by the calculated theoretical variance, where the smaller the variance the greater the reliability. Table 1 indicates a range in variance from 1.93 to 4.89 for samples in this study, with the majority of samples having a variance of approximately 3.

Other attempts have also been made to evaluate the reliability of the data. For example, although chemical data are limited for samples that also have point counting data, colour index data reflect chemistry (normative enstatite + hematite + ilmenite) and a plot of colour index against mafic mineral content (Fig. 6) for 11 samples indicates a reasonable correlation. The per cent mafic mineral content for all samples falls within ≈2% of a regression line through the data (Fig. 6) which, assuming a direct correlation between these variables, suggests an accuracy on point counting of ±2%.

In addition, the modal amounts of mafic minerals have been visually compared with known contents (Fig. 3). Although limited in degree of refinement, this process is reasonable for detecting substantial error (compare Fig. 3a-f with percentage values shown in 3g).The arrangement of slabs in relative order of mafic mineral content, as shown in Figure 3, also serves to indicate the difficulty in visually discerning small differences in the modal concentrations of mafic minerals and highlights the problem encountered in attempting to subdivide rocks of the Scrag Lake pluton in the field.

CONTOURING MODAL MAFIC MINERAL CONTENTS

In order to assess petrographic variation within the Scrag Lake pluton, the percentage values of mafic minerals determined from point counting were plotted on a map and contoured (Fig. 7). The contouring establishes well defined regional trends in mafic mineral content. These trends, in the broadest sense, define a crude petrographic zonation toward a less mafic core. Although local irregularity exists in this regional trend, considering the numerous parameters involved in establishing the percentages of mafic minerals (outcrop scale

Table 1. Data related to the modal analysis of mafic mineral content of samples from the Scrag Lake pluton: Sample = the sample number. The five-character prefix identifies the NTS map sheet (location of sample shown in Fig. 5); % MM = the calculated per cent mafic minerals determined from point counting; A = the area (mm^2) examined; PC = number of points counted; V = the calculated theoretical variance (see text for explanation).

Sample	% MM	A	PC	V
21/A05-0001	19.2	8100	900	3.82
21/A05-0004	21.3	8100	900	4.23
21/A05-0005	24.6	8100	900	4.89
21/A05-0007	16.6	9801	1089	3.30
21/A05-0008	17	8100	900	3.38
21/A05-0009	20.4	5436	604	4.05
21/A05-0013	21.3	17676	1964	4.23
21/A05-0015-31	13.6	8100	900	2.70
21/A05-0016	16.7	9801	1089	3.32
21/A05-0018-1	19.7	8100	900	3.92
21/A05-0021	18.2	8100	900	3.62
21/A05-0021	19.7	8100	900	3.92
21/A05-0030	15.9	8100	900	3.16
21/A05-0031	17.7	8100	900	3.52
21/A05-0033	18.9	8100	900	3.76
21/A05-0034	15.1	8100	900	3.00
21/A05-0035	15.1	6660	740	3.00
21/A05-1001	18.3	6480	720	3.64
21/A05-1003	19.7	6030	670	3.92
21/A05-1005	13	8100	900	2.58
21/A05-1007-1	17.8	8100	900	3.54
21/A05-1007-1	19	8100	900	3.78
21/A05-1009	19	7065	785	3.78
21/A05-1010	17.1	7407	823	3.40
21/A05-1011	20.1	8100	900	3.99
21/A05-1015	18.7	8100	900	3.72
21/A05-1016	16.1	8208	912	3.20
21/A05-8001	17.1	8100	900	3.40
21/A05-8004	18	8100	900	3.58
21/A05-8004	17	8100	900	3.38
21/A05-8006	18.7	8037	893	3.72
21/A05-8007	17.7	8100	900	3.52
21/A05-8010	18.2	6120	680	3.62
21/A05-8011	22.7	6750	750	4.51
21/A05-8013	14.7	5697	633	2.92
21/A05-8014	21.4	8100	900	4.25
21/A05-8015-1	20	7803	867	3.97
21/A05-8030	19.5	5670	630	3.88
21/A05-8032	16.8	8100	900	3.34
21/A05-8032	19	7524	836	3.78
21/A05-8036	20.6	9045	1005	4.09
21/A06-3013	18.2	5742	638	3.62
21/A06-3015	17.7	5742	638	3.52
21/A06-3016	13	7317	813	2.58
21/A06-3017	16.3	5742	638	3.24
21/A06-3030	16.1	7362	818	3.20
21/A10-3079	19.5	10341	1149	3.88
21/A10-3086	17.2	8298	922	3.42
21/A10-3098	15.3	7326	841	3.04
21/A10-3098-1	23.2	6453	717	4.61
21/A10-3105	18.9	9747	1083	3.76
21/A10-3106	20	8487	943	3.97
21/A10-3118	17.6	9549	1061	3.50
21/A10-3155	15.7	9801	1089	3.12
21/A10-3157	17.1	9801	1089	3.40
21/A11-2260	17.5	8100	900	3.48
21/A11-2261	15.6	8100	900	3.10
21/A11-2267	19.9	9333	1037	3.95
21/A11-2271	9.7	9792	1088	1.93
21/A11-2274	15.6	8100	900	3.10
21/A11-2275	15	7956	884	2.98
21/A11-2277	13.3	9801	1089	2.64
21A/11-2280	13.5	11349	1261	2.68
21/A11-2283	10.6	6552	728	2.11
21/A11-2306	14	8100	900	2.78
21/A11-2316	15.3	9630	1070	3.04
21/A11-3002	16	7101	789	3.18
21/A11-3006	13	11493	1277	2.58
21/A11-3008	18.3	5796	644	3.64
21/A11-3009	14.1	8100	900	2.80
21/A11-3017	18.4	8100	900	3.66
21/A11-3018	14.4	8100	900	2.86
21/A11-3019	16.7	8100	900	3.32
21/A11-3023	10.7	7848	872	2.13
21/A11-3025	14.9	9801	1089	2.96
21/A11-3026-1	17.6	8100	900	3.50
21/A11-3027	20.4	8100	900	4.05
21/A11-3029	18.7	8100	900	3.72
21/A11-3030	12.9	8838	982	2.56
21/A11-3031	14.7	11232	1248	2.92
21/A11-3032	17.9	8100	900	3.56
21/A11-3033	16.6	5490	610	3.30
21/A11-3034	17.4	6255	695	3.46
21/A11-3036	15.8	7614	846	3.14
21/A11-3037	17.3	8100	900	3.44
21/A11-3039	14.4	11223	1247	2.86
21/A11-3041-1	13.4	8658	962	2.66
21/A11-3045	12.9	8100	900	2.56
21/A11-3046	16.6	8100	900	3.30
21/A11-3049	10.1	7821	869	2.01
21/A11-3948-1	14.5	6039	671	2.88
21/A12-1002	16.1	9693	1077	3.20
21/A12-1003	20.3	9801	1089	4.03
21/A12-1008	15.2	9720	1080	3.02
21/A12-1010	18	9774	1086	3.58
21/A12-1017	12.9	5796	644	2.56
21/A12-1021	11.6	5796	644	2.31
21/A12-8002	20.2	9801	1089	4.01
21/A12-8011	21.1	8109	901	4.19
21/A12-8013	20.2	8469	941	4.01
21/A12-8016	16.3	5760	640	3.24
21/A12-8019	19.8	9585	1065	3.93
21/A12-8024	13.8	7668	852	2.74
21/A12-8025	18.1	6714	746	3.60
21/A14-0011	16.5	8910	990	3.28
21/A14-0016	15.1	8793	977	3.00
21/A14-0017	17.4	9288	1032	3.46
21/A14-0023	17.2	7686	854	3.42
21/A14-0027	14.7	8883	987	2.92
21/A14-0034	14.2	9729	1081	2.82
21/A14-0037	15	9801	1089	2.98
21/A14-1029	14.3	8100	900	2.84
21/A14-1033-1	13.7	8910	990	2.72
21/A14-1034	12.1	8100	900	2.40
21/A14-1038	14.6	9801	1089	2.90
21/A14-1048	14.2	9783	1087	2.82
21/A14-8002	16.4	8262	918	3.26
21/A14-8003	15.9	5850	650	3.16
21/A14-8005	13.6	6885	765	2.70
21/A14-8011	11.8	8910	990	2.35
21/A15-0103-2	16.4	7416	824	3.26
21/A15-0104	18.9	9450	1050	3.76
21/A15-0122	20.2	8100	900	4.01
21/A15-0145	15.9	8100	900	3.16
TEST 1	12	8100	900	2.38
TEST 2	14	8100	900	2.78
TEST 3	16	8100	900	3.18
TEST 4	18	8100	900	3.58
TEST 5	20	8100	900	3.97
TEST 6	22	8100	900	4.37
TEST 7	24	8100	900	4.77
TEST 8	15	8100	900	2.67
TEST 9	15	8100	900	2.98
TEST 10	15	8100	900	4.98

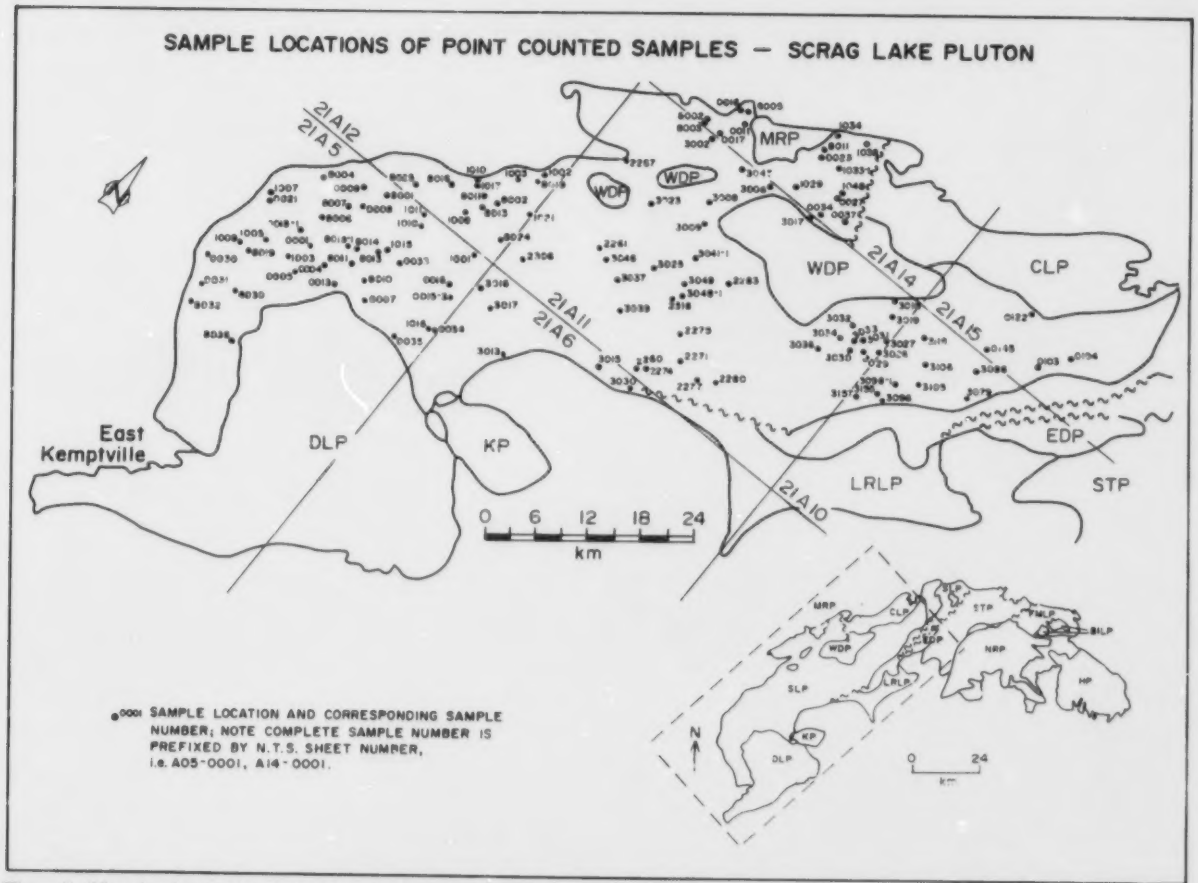

Figure 5. Map showing the location of samples from the Scrag Lake pluton that were point counted for mafic mineral content; sample numbers correspond to those in Table 1. See Figure 2b for explanation of abbreviations.

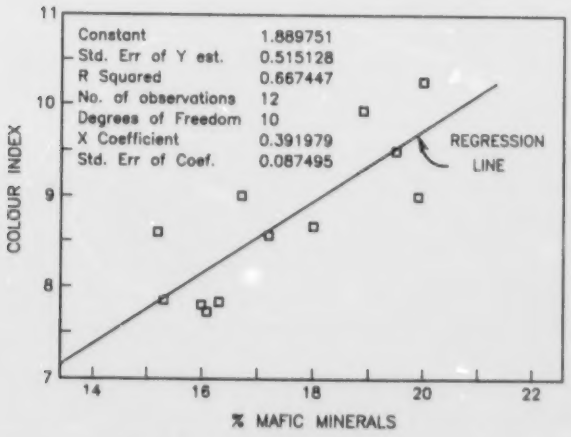

Figure 6. Plot of per cent mafic minerals determined from point counting versus colour index for selected samples of the Scrag Lake pluton.

variation, hand sample variation, the value of the calculated theoretical variance and the restricted range of the contour interval), the overall zonal pattern is significant.

A comparison of the contoured mafic mineral content (Fig. 7) with airborne eTh/K ratio data for the same area (Fig. 8) indicates a good correlation in the general pattern shown by both, with high mafic mineral content reflected by high eTh/K ratios and low mafic mineral contents reflected by low eTh/K ratios. This general correlation on one hand enhances the credibility of the point counting data and on the other hand suggests the variation in eTh/K is related to petrographic variation. Assuming this to be the case, the pattern displayed for eTh/K over the area of the Scrag Lake pluton is likely a more accurate reflection of petrographic variation within this pluton than is the contoured mafic mineral content. The reason for this is that the eTh/K values account for integrated values over the entire area whereas the detail of contoured

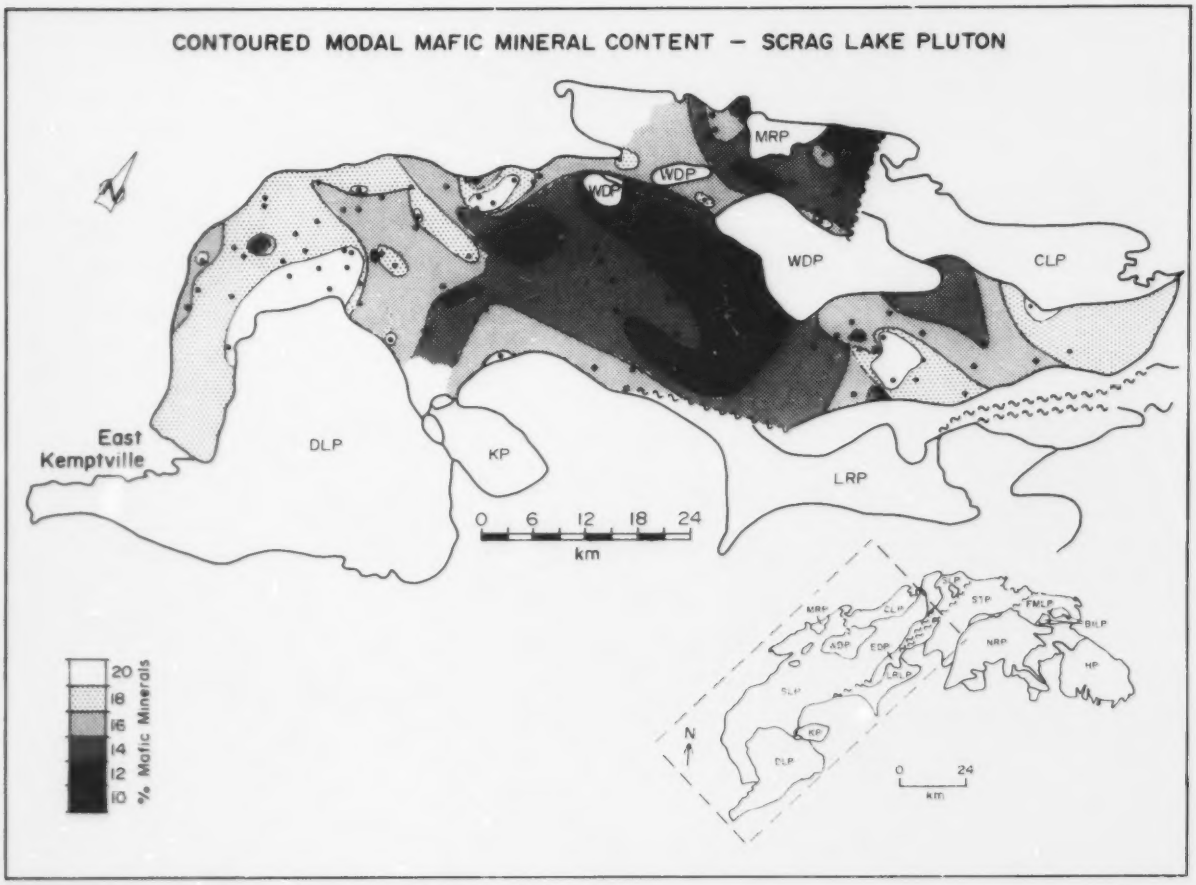

Figure 7. Contour map of mafic mineral content in the Scrag Lake pluton.

mafic mineral contents is limited by the density of data and affected by the parameters controlling the determined mafic mineral content.

DISCUSSION

The above exercise has demonstrated that the Scrag Lake pluton is petrographically zoned with respect to mafic mineral content. Comparison of average petrographic and chemical variables for the major rock types within the South Mountain Batholith indicates a general relationship between the degree of chemical evolution and the mafic mineral content. For example, decreasing average modal mafic mineral content for the various rock types from granodiorite to leucogranite corresponds to increasing average values of differentiation index (Ham *et al.*, 1990). Assuming that colour index reflects the mafic mineral content, a strong correlation between mafic mineral content (colour index) and differentiation index is shown for samples from the Scrag Lake pluton (Fig. 9). This suggests the variation in mafic mineral content of the Scrag Lake pluton reflects 'general' petrographic and chemical variation and is consistent with interpretations that chemical trends in the batholith reflect progressive fractionation of biotite and plagioclase (McKenzie and Clarke, 1975). It is, therefore, reasonable to interpret the zonal pattern displayed by the percentage of modal mafic minerals in the Scrag Lake pluton as reflecting 'normal' petrographic and chemical zonation related to inward fractional crystallization of a single, large magma chamber.

The identification of petrographic zoning within the Scrag Lake pluton also serves to demonstrate the intrusive relationship between the Scrag Lake pluton and several Stage 2 plutons. It is apparent in Figure 7 that the West Dalhousie, Davis Lake, Morse Road and East Dalhousie plutons truncate the petrographic zonation defined within the Scrag

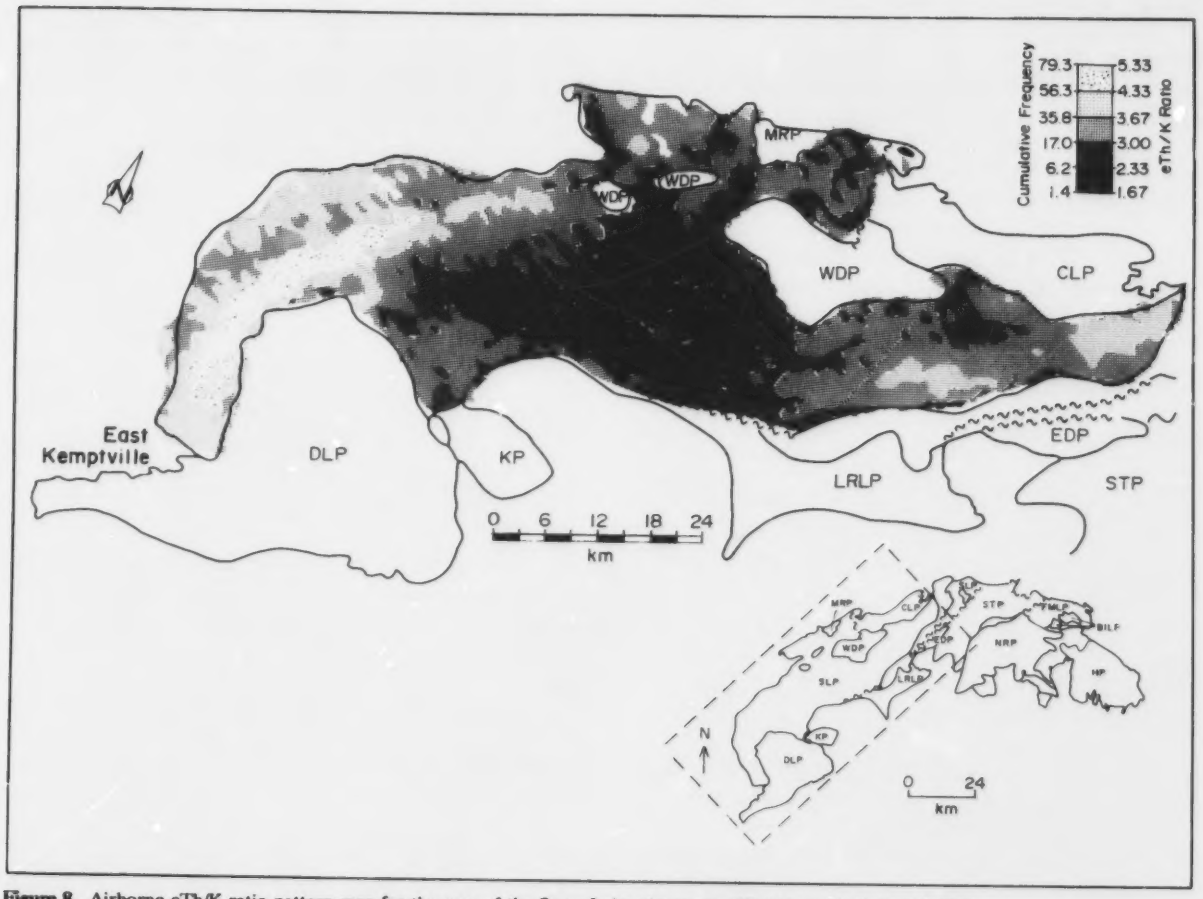

Figure 8. Airborne eTh/K ratio pattern map for the area of the Scrag Lake pluton; modified from Ford et al. (1989).

Lake pluton and thus intrude it, confirming the respective Stage 2 and Stage 1 designations.

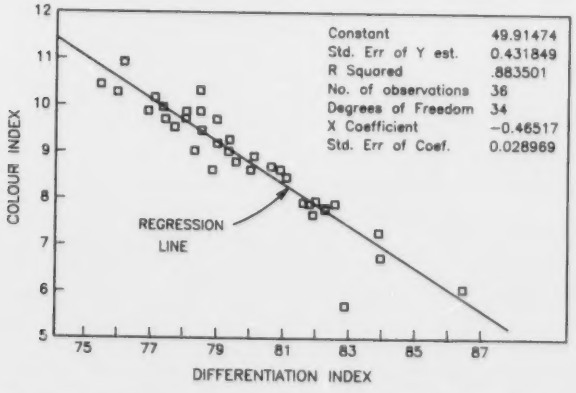

Figure 9. Plot of differentiation index vs. colour index for selected samples from the Scrag Lake pluton.

REFERENCES

Bateman, P. C. and Nokleberg, W. J. 1978: Solidification of the Mount Givens Granodiorite, Serra Nevada, Califorina; Journal of Geology, v. 86, p. 563-579.

Chatterjee, A. K. and Ham, L. J. 1991: U-Th-Pb systematics of the South Mountain Batholith, Nova Scotia; abstract, Atlantic Geoscience Society Colloquium, Amherst, Nova Scotia, February 1991.

Chatterjee, A. K. and Horne, R. J. 1991: Variations in LIL elements, HFS elements and REES within the Davis Lake Pluton, southwestern Nova Scotia; abstract, Atlantic Geoscience Society Colloquium, Amherst, Nova Scotia, February 1991.

Corey, M. C. 1987: A reinterpretation of U-Th ratios in the New Ross area: evidence for a zoned pluton; *in* Mines and Minerals Branch, Report of Activities 1987, Part A, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 87-5, p. 105-108.

Ford, K. L., Carson, J. M., Grant, J. A. and Holman, P. B. 1989: Equivalent Thorium/ Potassium Radioactivity Map of Nova Scotia; Geological Survey of Canada, Map 35006G, scale 1:500 000, sheet 7 of 9.

Ham, L. J., Corey, M. C., Horne, R. J. and MacDonald, M. A. 1990: Lithogeochemistry of the western portion of the South Mountain Batholith, Nova Scotia, N.T.S. map sheets 21A/3, 21A/4, 21A/5, 21A/6, 21A/11, 21A/12 and 21A/ 14; Nova Scotia Department of Mines and Energy, Open File Report 90-007.

Harper, C. L. 1988: On the nature of time in the cosmological perspective; unpublished Ph.D. thesis, Oxford University, 508 p.

Horne, R. J., Corey, M. C., Ham, L. J. and MacDonald, M. A. 1989: Lithogeochemical variation within the biotite-rich envelope rocks of the eastern South Mountain Batholith: implications for its intrusive and post-intrusive history; *in* Mines and Minerals Branch, Report of Activities 1988, Part B, eds. Y. Brown and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 89-1, p. 37-50.

MacDonald, M. A., Corey, M. C., Ham, L. J., Horne, R. J. and Chatterjee, A. K. 1990: Recent advances in the geology of the South Mountain Batholith: anatomy and origin of a batholith; abstract in Atlantic Geology, v. 26, no. 2, p. 180.

MacDonald, M. A., Corey, M. C., Ham L. J. and Horne R. J. 1989: Petrographic and geochemical aspects of the South Mountain Batholith; *in* Mines and Minerals Branch, Report of Activities 1989, Part A, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Mines and Energy, Report 89-3, p. 75-80.

MacDonald, M. A. and Horne, R. J. 1988: Petrology of the zoned, peraluminous Halifax Pluton, south-central Nova Scotia; Maritime Sediments and Atlantic Geology, v. 24, p. 33-46.

McKenzie, C. B. and Clarke D. B. 1975: Petrology of the South Mountain Batholith, Nova Scotia; Canadian Journal of Earth Sciences, v. 12, p. 1209-1218.

Solomon, M. 1963: Counting and sampling error in modal analysis by point counter; Journal of Petrology, v. 4, p. 367-382.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 61-73

A MINERALOGICAL AND FLUID INCLUSION STUDY OF THE WEST GORE Sb-Au DEPOSIT, MEGUMA TERRANE, SOUTHERN NOVA SCOTIA[1]

D. J. Kontak and P. K. Smith

INTRODUCTION

Examination of the metallogenic map of Nova Scotia (Chatterjee, 1983) reveals the uniqueness of the West Gore Sb-Au district (Fig. 1) with respect to the presence of antimony associated with gold. This association is unusual in Meguma Group gold deposits, as antimony mineralization is rarely, if ever, recorded as a trace constituent of mineralized veins in the Meguma Group (e.g. Malcolm, 1929), although elevated antimony contents are sometimes recorded in analysis of arsenopyrite. However, the metallogenic association of Au and Sb is common elsewhere in metasedimentary-dominated terrains of lower Paleozoic age, as in New Zealand (Henley *et al.*, 1976; Paterson, 1982, 1986), Ireland (Steed

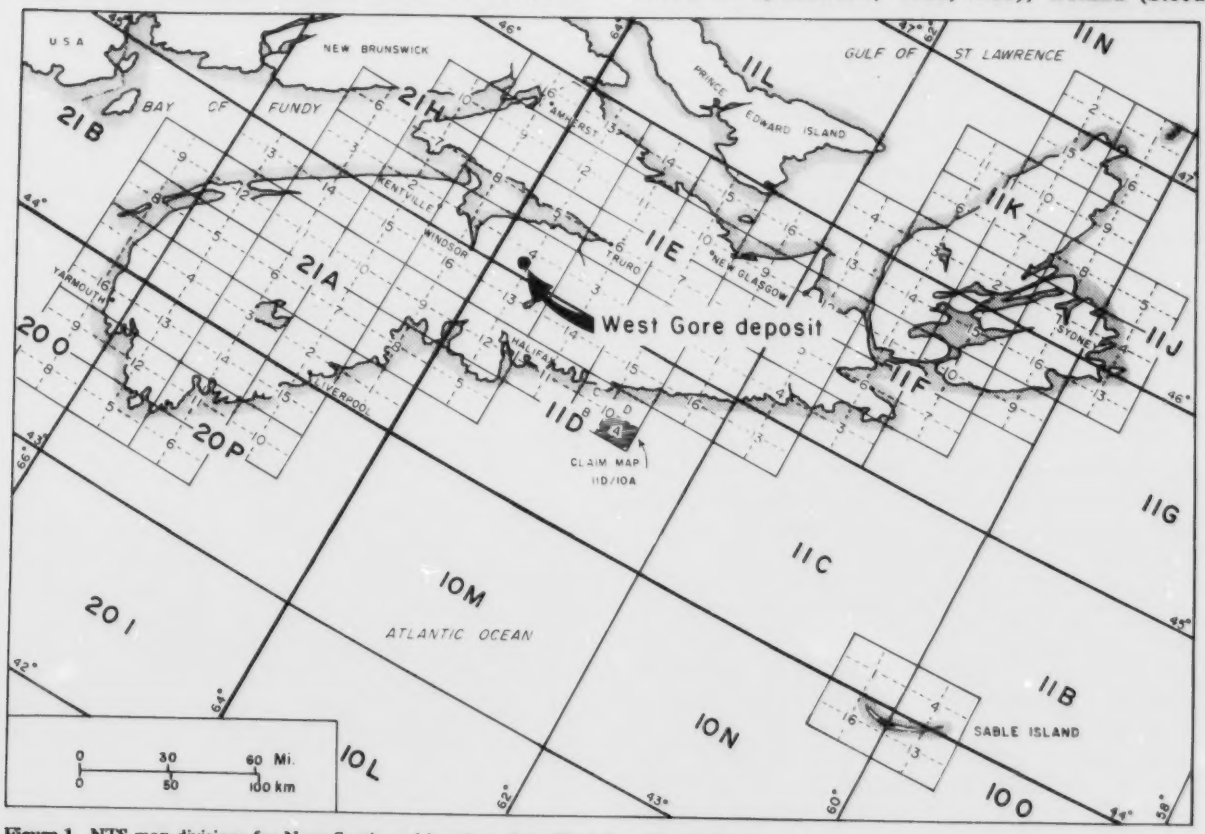

Figure 1. NTS map divisions for Nova Scotia and location of the West Gore Sb-Au deposit.

1 Funded by Nova Scotia Department of Mines and Energy under the Canada - Nova Scotia Corporation Agreement on Mineral Development 1990-1992

and Morris, 1986), Australia (O'Shea and Pertzel, 1988), British Columbia (Madu *et al.*, 1990) and Bolivia (Ahlfeld and Schneider-Scherbina, 1964). In addition, Colvine *et al.* (1984) and Nesbitt and Muehlenbachs (1989) note the association of antimony with mesothermal lode gold deposits of the Superior Province and Canadian Cordillera, respectively. Additional areas of antimony mineralization in the Canadian Appalachians include the Moreton's Harbour area of Newfoundland (Kay and Strong, 1983), which is hosted by mafic and felsic volcanic rocks, and the world-class Lake George antimony deposit of New Brunswick (Morrissy and Ruitenberg, 1980), hosted by Silurian metaturbidites but related to a shallow-level granite intrusion (Seal *et al.*, 1987).

In this paper, preliminary results are presented from a mineralogical and fluid inclusion study of specimens from the old mine workings of the West Gore deposit. The study was initiated in order to expand the database for the Meguma lode gold deposits (Kontak *et al.*, 1990a) and, in particular, because of the obvious departure of the mineral association from the majority of Meguma Group deposits. In this paper we present a summary of work to date, compare the results to those for other Meguma gold deposits, and discuss implications for the origin of Meguma gold deposits in general.

Geological Setting

The West Gore area is located in the Rawdon Hills of Hants County, southern Nova Scotia (Fig. 2), and is about 5 km northwest of the old Rawdon gold district. The district occurs within lower Paleozoic metasedimentary rocks of the Meguma Group, but near the fault contact with younger clastic sediments of the Lower Carboniferous Horton Group. The local strata consist of black slate of the Halifax Formation, youngest member of the Meguma Group, trending northeast and dipping 45° toward the southeast. A gentle warp in the stratigraphy outlines the West Gore Anticline. Its axial trace is located approximately 1 km northwest of the deposit and there are numerous northwest-trending, subvertical faults in the area. The metamorphic grade in the area is low and schistosity is poorly developed, but Douglas and MacDonald (1940) noted that near fault planes the slate is intensely sericitized. Some drag folds occur in the slate and these have axial planes that trend northeast and dip parallel to but slightly steeper than bedding.

Nature of Mineralization and Veining

Historical production from the West Gore district has been estimated at approximately 7761 tons of antimony concentrate (46% Sb; Messervey, 1932) and 7149 oz. of gold (Bates, 1987). However, it is significant to note that about 90% of the antimony mined remained at the site as a low-grade (i.e. 10% Sb) concentrate and that for several years during the initial mining phase the auriferous nature of the ore went unnoticed. In addition, much of the gold occurs as fine grained intergrowths with antimony minerals and was not amenable to recovery at the time; hence, it may be assumed that considerable amounts of gold were not recovered.

Mineralization at West Gore is localized exclusively in northwest-trending fissure veins (ac type using the nomenclature of Henderson and Henderson, 1986), which contrasts to the general association of mineralization with bedding-parallel veins in the Meguma gold districts (Malcolm, 1929). Nine principal veins were identified at West Gore, although only seven are mineralized, and they can be grouped into three subparallel vein systems (Fig. 2). The veins, consisting predominantly of quartz + stibnite ± crushed slate ± carbonate, are generally 10-15 cm wide but may be up to 50 cm wide, and where mineralized they were mined to a depth of about 250 m and along strike for about 400 m (Douglas and MacDonald, 1940; Malcolm, 1929). The ore occurred in distinct ore shoots which were oriented subparallel to the northeast-trending fold axis of the drag folds (see Fig. 8 in Douglas and MacDonald, 1940).

METHODS OF INVESTIGATION

This study has focused on specimens collected from the remaining dump piles at the abandoned West Gore district with no presumption that these specimens collected are representative of the entire ore body mined. Routine petrographic study was done with transmitted and reflected light microscopy and some preliminary microprobe analysis (JEOL 733 Superprobe at the Department of Geology, Dalhousie University) was performed on some of the more complex phases. Fluid inclusion studies were done on four vein specimens,

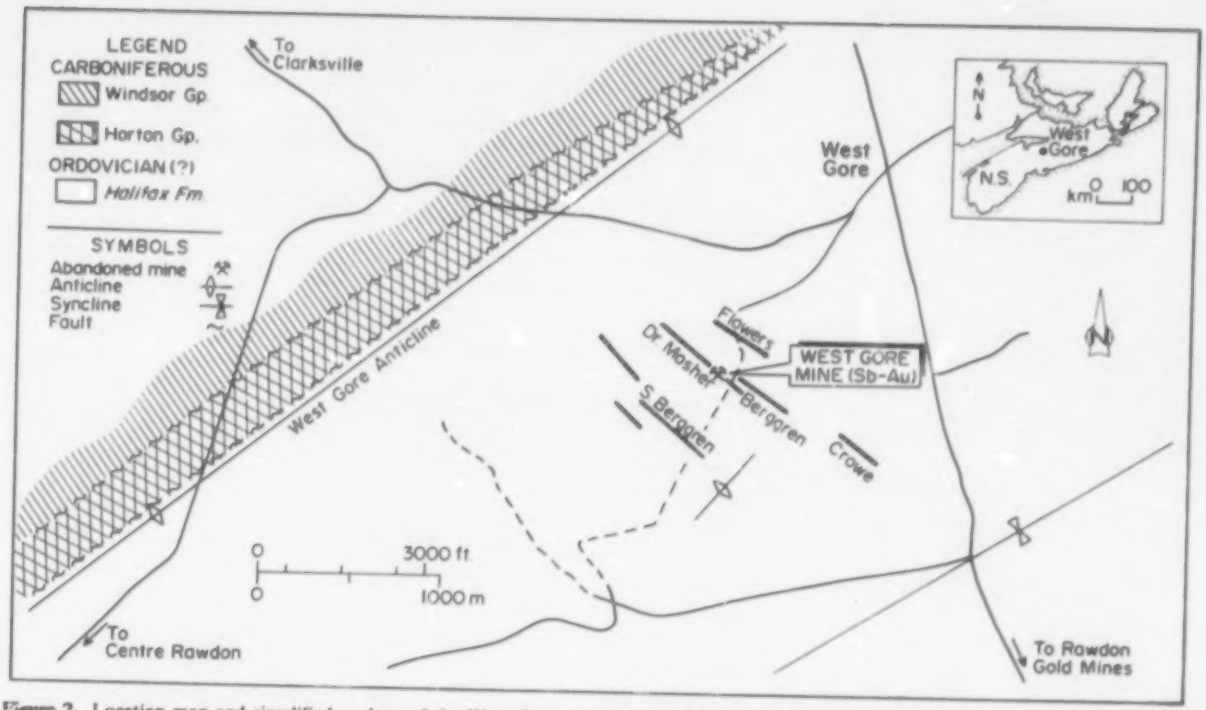

Figure 2. Location map and simplified geology of the West Gore deposit area showing the principal veins. Note that the veins trend to the northwest, approximately orthogonal to the trace of the West Gore Anticline.

but to date only quartz has been examined for inclusions. Thermometric measurements were obtained using a Fluid Inc. modified U.S.G.S. gas flow heating-freezing stage (Roedder, 1984), calibrated with synthetic standards.

VEIN PARAGENESIS AND TIMING OF MINERALIZATION

Detailed examination of polished thin sections and hand specimens indicate that vein mineralization at West Gore can be subdivided into four main stages based on mutual textural relationships, namely: (1) quartz infill, (2) main stibnite stage, (3A) carbonate-chlorite, (3B) Au-Sb±Zn±Pb±Cu and (4) oxide. Commensurate with the formation of vein material is wall rock alteration, as observed in wall rock fragments in the veins. Note that the term 'stage' has no absolute temporal significance and that several stages of mineralization may have co-existed on the deposit scale at any one time, although on a local scale (i.e. hand sample) there was a continuous and systematic progression through the paragenesis. The paragenesis is summarized in Figure 3 with the list of phases identified to date. The salient features of the veins, as observed during microscopic examination, are summarized in Figures 4 and 5.

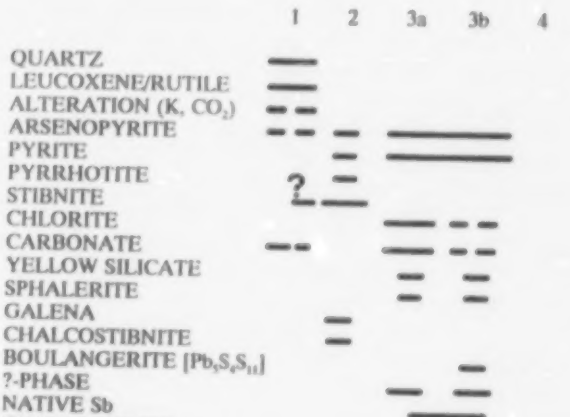

Figure 3. Mineral paragenesis at West Gore subdivided into the four stages discussed in text.

Stage 1

This stage consists almost exclusively of quartz and accounts for the main period of vein fill. However, some co-crystallization of stibnite occurred during this stage, as indicated by interpenetrating textural relationships. Quartz grain size is generally bimodal, invariably euhedral, and of equant to prismatic habit (Fig. 4c, 4d, 4e, 4f): textural features characteristic of epizonal conditions of formation (Dowling and Morrison, 1989). Quartz grains are often cloudy in the cores due to the inundation of fluid inclusions (Fig. 4e and see below) and rarely does the quartz show signs of deformation (i.e. subgrain development, undulatory extinction). Rare carbonate occurs as an open-space fill in the pore space between euhedral quartz vein material.

Also present in this stage is incorporation of wall rock slate as inclusions (Figs. 4a, 4b, 4c). The presence of secondary muscovite, carbonate and replacement of ilmenite porphyroblasts by leucoxene/rutile suggests reaction of wall rock inclusions with the vein-forming fluid. A most important observation with respect to the wall rock inclusions is the presence of arsenopyrite euhedra overgrowing and clearly truncating a well-defined lepidoblastic fabric in the slate (Fig. 4a, 4b, 4c). The arsenopyrite is not surrounded by pressure shadows (Fig. 4b) and in some cases grows from the slate inclusion into surrounding, euhedral quartz of the vein fill (Fig. 4c). Observations of the quartz textures and the wall rock inclusions indicate that vein formation post-dated regional deformation of the host Halifax Formation (i.e. $<400 \pm 10$ Ma). A specimen of phyllically-altered wall rock is currently being analyzed by the $^{40}Ar/^{39}Ar$ technique to establish an absolute age of vein formation.

Stage 2

This stage is dominated by the formation of stibnite (Fig. 4e, 4f), the main antimony ore mineral at West Gore, and minor amounts of associated pyrite, pyrrhotite and arsenopyrite (Fig. 4f). The stibnite occurs as massive clots infilling pore space within quartz euhedra, as subparallel veinlets cross-cutting quartz and as euhedral, prismatic crystals that penetrate the surrounding quartz and generally eminate from the previous two morphotypes of stibnite. The stibnite occurs locally in close association with pyrrhotite and complex textural relationships suggest that both phases may co-exist or, alternatively, replace each other (e.g. pyrrhotite replacing stibnite in Fig. 5a). Small inclusions of pyrrhotite may also occur randomly distributed within stibnite and the same may be said of chalcostibnite and galena. Pyrite and arsenopyrite occur as fine to coarse, euhedral grains and (or) aggregates, either in close association with stibnite or in isolation (Fig. 4f), and they are also found together in cross-cutting fractures.

Stages 3A and 3B

These substages of stage 3 are characterized by the presence of chlorite + carbonate, which occur in isolation (Fig. 5b) or as an overprinting of the previous vein assemblage, including the apparent dissolution of earlier stibnite (Fig. 5d). It is difficult to completely separate the substages, but there appears to be widespread development of chlorite + carbonate commensurate with corrosion of stibnite, but not always involving the formation of native gold and gold alloys.

Included in stage 3A is the presence of native antimony, incipient development of an Au-Sb alloy within stibnite (Figs. 5c, 5f), associated sulphides of pyrite, arsenopyrite and sphalerite, and an unidentified phase that occurs as disseminations within stibnite. Sphalerite is characterized by its transparent nature in transmitted light with a yellowish-red colour indicating only moderate iron content. This stage is variable in development, but may sometimes involve almost complete replacement of earlier stibnite by native Sb + sulphides + Au-Sb alloy.

Stage 3B involves continuation of the previous assemblage, but also includes the addition of native gold, an increase in the abundance of Sb- and Cu-alloys, boulangerite, electrum (?) and chalcopyrite (Figs. 5c, 5e, 5f). Native gold occurs (1) replacing stibnite (Figs. 5c, 5e, 5f), (2) as equidimensional free grains of ca. 50-100 μm size in quartz (Fig. 5f), (3) as delicate crusts on euhedral quartz prisms (Fig. 5f), and (4) as intricate crystalline forms intergrown with various Sb- and Cu-alloys (Fig. 5e). This latter morphotype is identical to rheingold described by Ramdhor (1980).

Stage 4

This stage is characterized by the presence of antimony oxide minerals (kermesite and valentinite) and iron-oxide coatings.

MINERAL CHEMISTRY

Although complete chemical analysis of the mineral phases is planned, only preliminary data on the gold phases are presently available. This work indicates that free grains of gold have a fineness of >990, whereas the rheingold contains between 3-10 wt.% Sb. In addition, mixtures of Au with Cu and Sb, herein referred to as alloys, have been identified by semi-quantitative analyses and from the approximate atomic proportions are tentatively identified as cyprian gold (cuproauride) and aurostibnite ($AuSb_2$) using the terminology of Boyle (1979, his Table 6).

FLUID INCLUSION STUDIES

Fluid inclusions provide the only access to the actual fluid phase present during vein and ore formation; hence, they are an invaluable means of obtaining information on the physio-chemical conditions attending mineralization. In the present investigation observations are confined to quartz material and as the paragenesis above indicates, this mineral is inferred to predate much of the ore stage. Thus, with these limitations in mind, the types of fluid inclusions and their thermometric properties are described below.

Petrographic Observations

Vein quartz at West Gore is generally inundated with fluid inclusions and these are often found concentrated in the core areas of individual crystals or forming a concentric pattern that is coincident with growth faces (Figs. 6a, 6b, 6c, 6d). In addition, inclusions are found aligned along healed microfractures that terminate within the quartz and are in turn overgrown by inclusion-free quartz. The features described for the fluid inclusions are diagnostic of primary and pseudosecondary inclusions (Roedder, 1984).

In more detail, the inclusions may be subdivided into three types, which in decreasing order of relative abundance are: (1) vapour (V)-rich, (2) liquid (L)-rich, and (3) H_2O-CO_2 type (X_{CO2} = 0.1-0.15). The first two types may be considered as primary and pseudosecondary, while the third type is probably pseudosecondary to secondary. Type 1 and 2 inclusions are abundant and coexist along healed fracture planes (Figs. 6e, 6f), suggesting that fluid unmixing occurred. Type 1 inclusions are of very irregular shape and are similar in all respects to those shown by Bodnar *et al.* (1985; their Fig. 5) to illustrate fluid unmixing in an epithermal environment. Type 2 inclusions are generally more equant to elongate, although irregular-shaped ones also occur. Both type 1 and 2 inclusions are generally <10-15 μm in size. Type 3 inclusions have only been observed in two specimens. These inclusions, numbering about 25-30, were both V- and L-dominated, although the latter were more common, and of 10-40 μm size. Although all specimens were examined thoroughly for fluid inclusions, no inclusions were observed to contain solid phases such as halite.

Thermometric Measurements

Fluid inclusion chips were cooled to about -100°C, then slowly heated and all phase changes recorded until final homogenization of the inclusion was observed. The results of these measurements are summarized in Figure 7 and reviewed below commencing with the lowest temperatures.

Results of Freezing Runs

In the samples containing H_2O-CO_2 inclusions, melting of CO_2 occurred in the narrow interval of -57 to -61.1°C with a mean temperature of -58.6 ± 1.0°C (Fig. 7a). This indicates that a minor amount of a dissolved species, in addition to CO_2, is present since T_m of pure CO_2 is -56.6°C. This additional phase is probably CH_4.

First melting temperatures were noted to vary considerably and, although not consistent, values in the range -35±5°C indicate the presence of some $FeCl_2$. The temperature of ice disappearance (Tm_{ice}) varies from -10 to -2°C with most data in the range -3 to -5.5°C, corresponding to salinities of approximately 4-8 equivalent wt.% NaCl (Fig. 7b). However, these must be considered as an over-estimate since clathrate (CO_2 5.75 H_2O) formation was observed. A more conservative estimate for salinity is taken to be about 5 wt.% equivalent NaCl. Clathrate melting temperatures also provide an estimate of salinity and using the limiting values of

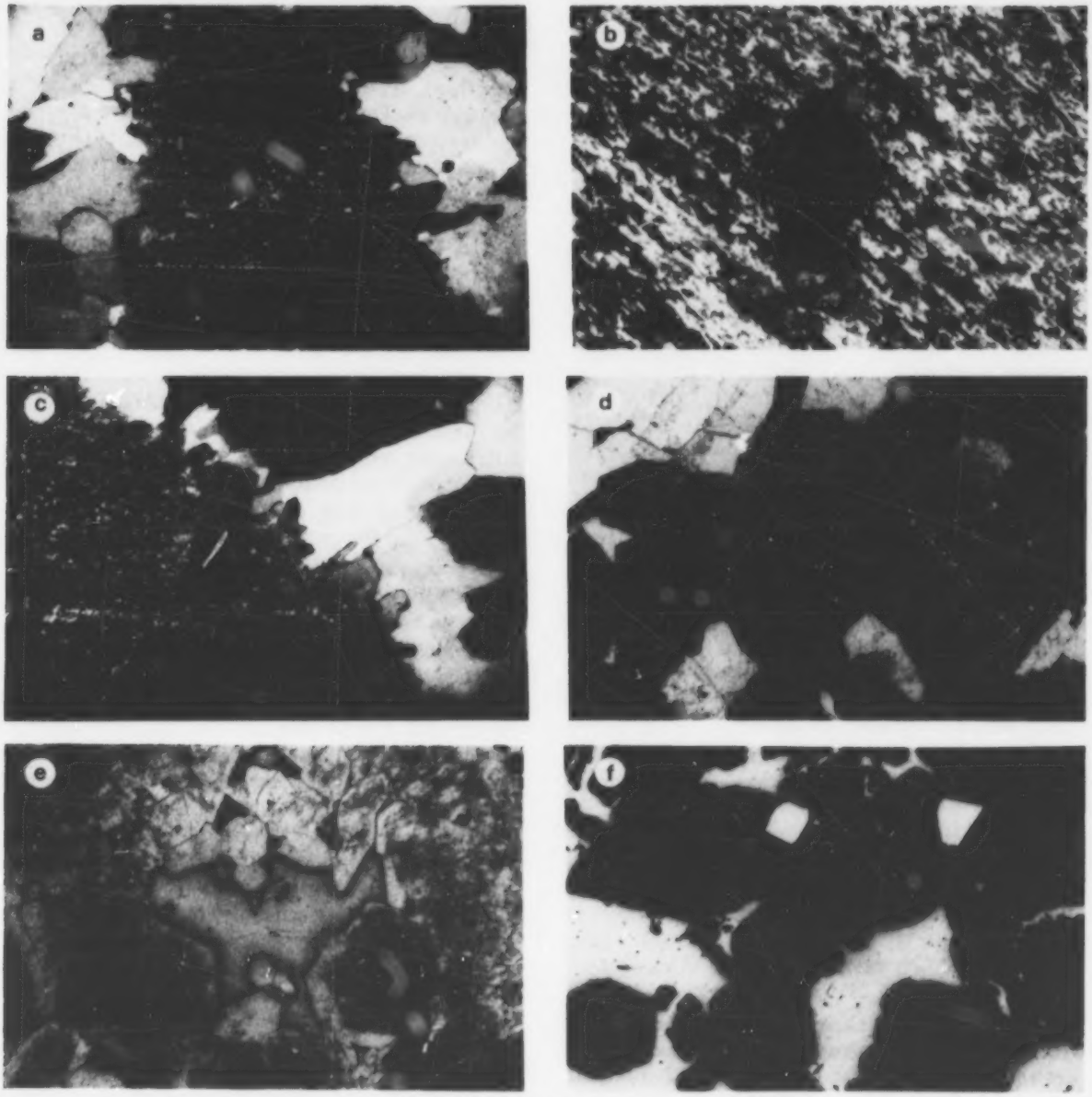

Figure 4. Photomicrographs of vein and wall rock inclusions at West Gore. Photos 4a to 4e were taken in transmitted light while 4f was taken with reflected light. (a) Wall rock inclusion with east-west schistosity defined by mica. Note the euhedral arsenopyrite crystal in the centre of photo. (b) Enlargement of Figure 4a showing the euhedral arsenopyrite crystal overgrowing the lepidioblastic fabric. Note the lack of pressure shadows around the arsenopyrite, which indicates post-kinematic growth of the crystal. (c) Wall rock inclusion showing an arsenopyrite crystal overgrowing the fabric and penetrating the surrounding, unstrained quartz vein material. Note that the c axis of quartz grows orthogonal to the wall rock inclusion. (d) Undeformed, equidimensional quartz euhedra infilling vein. (e) Stibnite (centre of photo) infilling pore space between quartz euhdra. Note the abundance of fluid inclusions in the quartz with clear overgrowths. (f) Stibnite (grey phase, lower right) in quartz (dark) and accessory arsenopyrite euhedra (bright).

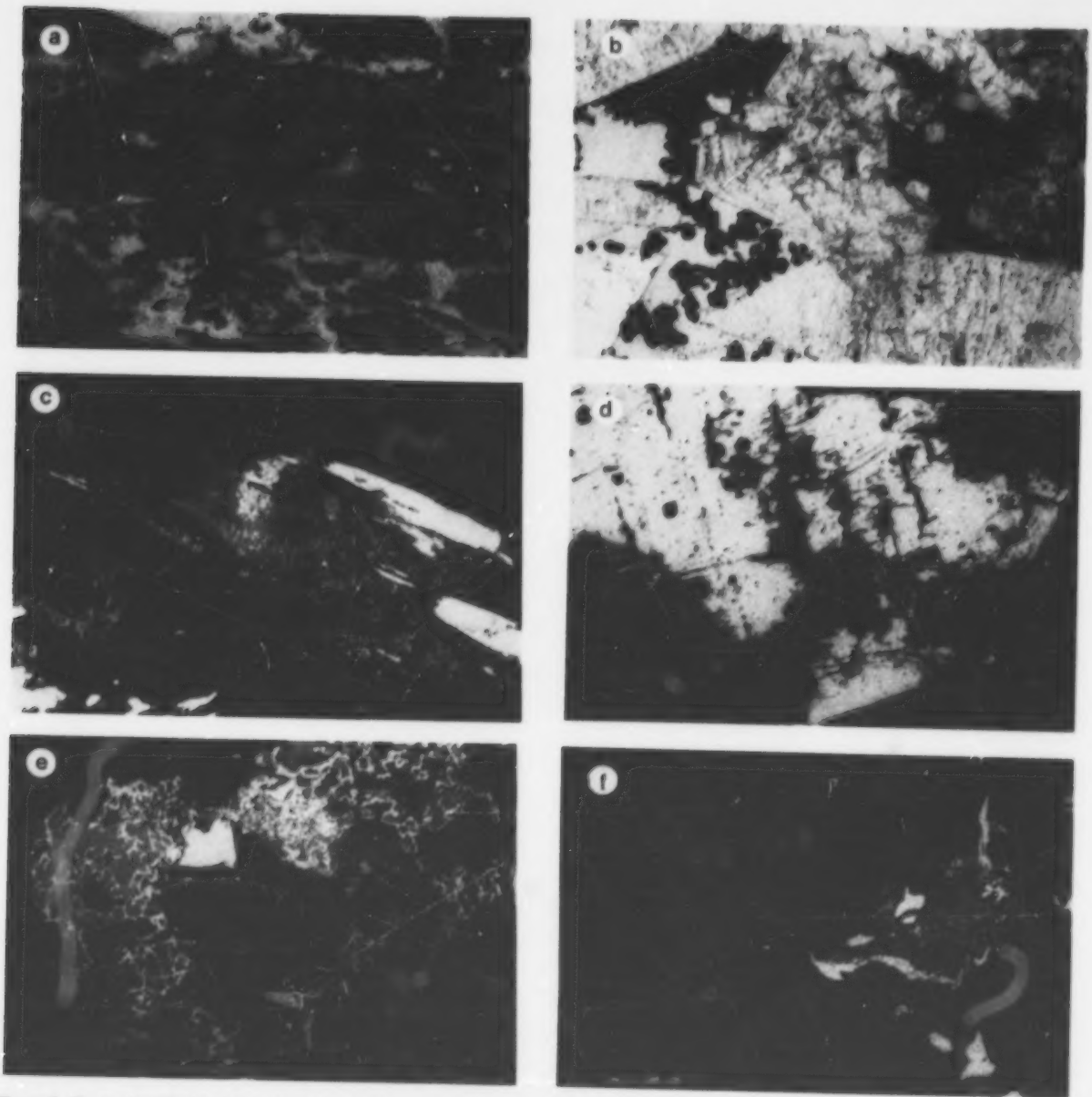

Figure 5. Photomicrographs of ore mineralogy at West Gore. All photos taken in reflected light except b (transmitted light). (a) Pyrrhotite (dark grey) intergrown with stibnite (light grey). (b) Chlorite and carbonte (dark areas) infilling pore space between quartz euhedra. (c) Au-Cu alloy phase and native gold (bright phase rimming the alloy) replacing stibnite (bright phase). (d) Stibnite (bright phase) being replaced by carbonate (dark phase penetrating stibnite); quartz euhedra form the background. Note the original shape of stibnite extended to the quartz grains on the right side of photo. (e) Close-up of Au-Cu alloy (dark phase with colloform texture) mantled by native gold (bright phase) and remnant stibnite. (f) Native gold mantling quartz euhedra (left side of photo) and as coarser, free grains in lower right. Also, native gold and gold alloys replacing stibnite in right side of photo.

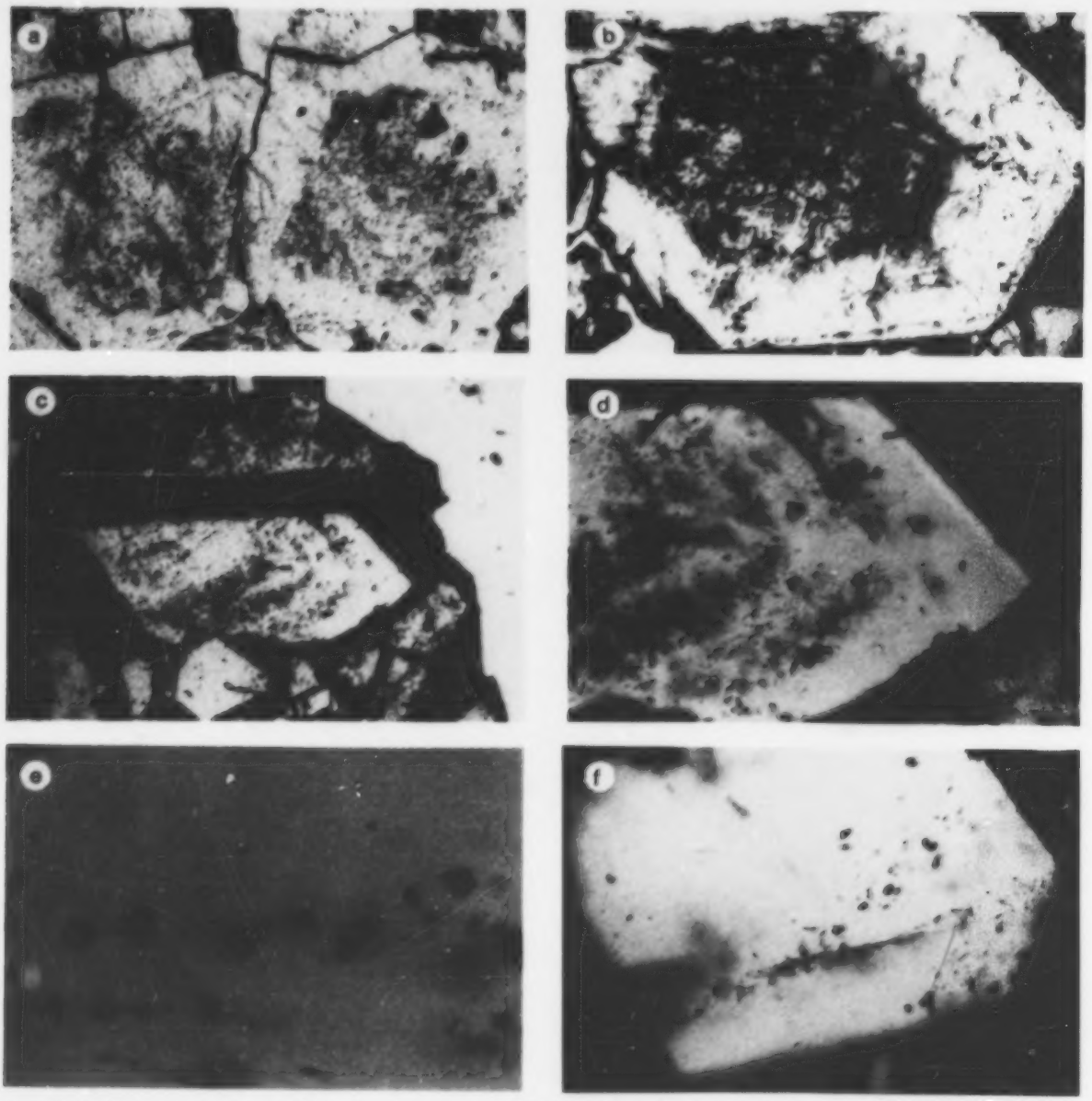

Figure 6. Photomicrographs of quartz illustrating the occurrence of fluid inclusions. All photos taken in plane-polarized transmitted light. (a) Euhedral quartz grains inundated with fluid inclusions in their cores with clear overgrowths. (b) Similar to (a). (c) Euhedral quartz grain showing zonal arrangement of primary fluid inclusions. (d) Close-up of part of Fig. 6c. (e) Vapour- and liquid-rich fluid inclusions (ca. 5-10 μm size) occurring along a healed fracture plane. (f) Vapour- and liquid-rich fluid inclusions (5-10 μm size) along healed fracture plane.

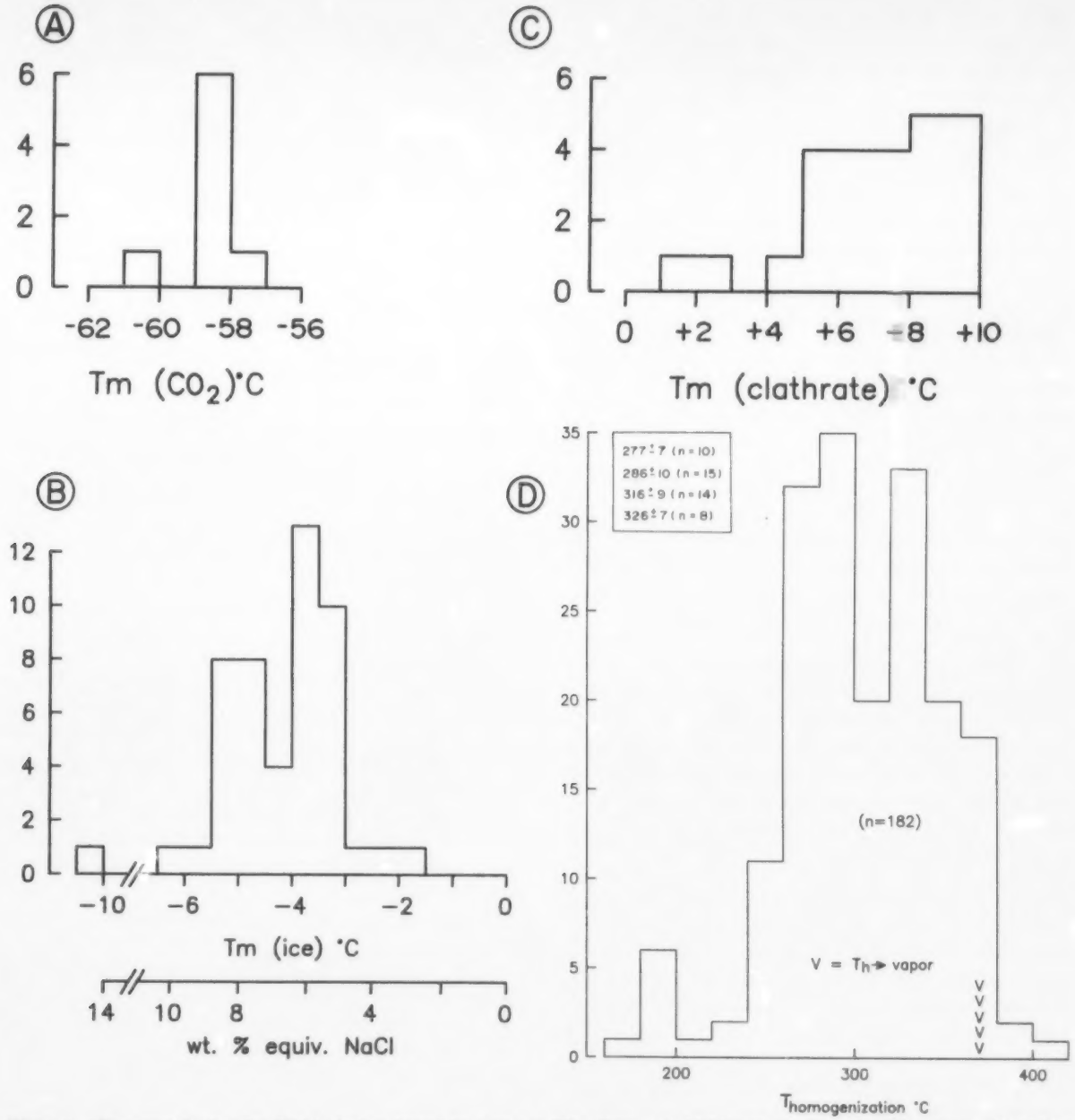

Figure 7. Thermometric data for fluid inclusions hosted by quartz at West Gore. (a) Melting temperatures for CO_2 phase. (b) Melting temperatures for ice. (c) Melting temperatures for CO_2 clathrate. (d) Final homogenization temperatures for H_2O inclusions. Note that five inclusions were homogenized by V expansion (indicated by V symbol).

+5 to +10°C, which encompass 90% of the data (Fig. 7c), salinities of approximately 0-8 wt.% equivalent NaCl are indicated. However, since the presence of minor CH_4 in the inclusions can artificially increase this value slightly, a more conservative estimate of salinity is probably about 5 wt.% equivalent NaCl.

Results of Heating Runs

Homogenization of the CO_2 phase occurred by vapour disappearance at +25.4±0.8°C, corresponding to a density of 0.7 g/cc for this phase. Final

homogenization temperatures for the inclusions (Fig. 7d) indicate a broad range from <200°C to 400°C, but the majority of data correspond to the range 250 to 350°C and, although not recorded accurately, abundant inclusions (in addition to the data shown) homogenized in the range 340-360°C. While most of the data measured recorded expansion of the liquid (L) phase, a few appropriately-shaped (i.e. contained embayments or horns), vapour (V)-rich inclusions homogenized at 370-380°C.

Interpretation of Fluid Inclusion Data

The petrographic observations and thermometric data indicate that the vein-forming fluids at West Gore consisted of low salinity brines with minor amounts of dissolved CO_2 (i.e. ~1 mole%). The homogenization data cover a broad range, but measurements for individual groups of inclusions define much more limited ranges with standard deviations for mean homogenization temperature (T_h) of only 7-10°C (Fig. 7d). Thus, entrapment of fluids of restricted temperature range occurred intermittently during growth of the quartz crystals. Important also is the observation that the upper limiting values for T_h by L phase expansion broadly correspond to the T_h data for V phase expansion. These data can be used to provide limiting constraints on the pressure of vein formation.

A minimum estimate of pressure is provided by using the boiling point curve for 5-10 wt.% equivalent NaCl and the 250 to 350°C T_h interval. In Figure 8a these data indicate a depth of vein formation of 400-1800 m assuming a hydrostatic head; lower values would be implied if a partial or complete lithostatic load was inferred (Roedder, 1984). A maximum limit of pressure is estimated using the 2-phase L - V curve for a 5 wt.% NaCl brine, the critical point (CP) of 405°C for such a solution, and the isochores for this solution projected from 250 and 350°C (Fig. 8b). Intersection of the isochores with the critical point indicates a limiting pressure of 0.9 to 2.2 kbar; the lower estimate is considered more realistic given (1) the T_h of the V-rich inclusions, (2) the petrographic observations indicating that fluid unmixing was occurring and (3) the observation of critical behaviour by a single inclusion (T_h of 350°C). Thus, the fluid inclusion data suggest that West Gore formed at <1 kbar pressure and approximately 3 km depth (assuming lithostatic load) or greater (if hydrostatic conditions apply).

Combining the T_h and Tm_{ice} (i.e. salinity) data into a binary plot (Fig. 8c), one notices that a possible correlation exists such that both salinity and temperature decrease systematically. This observation is frequently inferred to suggest mixing of fluids, generally involving meteoric water as the low temperature - low salinity end member. Although a larger database would be required to confirm this trend, the existing data are tentatively interpreted in this manner.

DISCUSSION AND CONCLUSIONS

The paragenetic sequence observed at West Gore can be integrated with fluid inclusion data to interpret the vein-forming event in terms of a genetic model. The four main stages of vein mineralization are interpreted to be sequential on a local scale with a certain degree of overlap between stages. While fluid inclusion data have only been obtained on quartz, it is inferred that boiling or fluid unmixing was an integral feature of the mineralizing process at West Gore with late incursion of low salinity fluids, possibly meteoric water. This latter scenario is inferred to accommodate the obvious change in chemical conditions indicated by the ore assemblage and paragenesis, which required changes in physio-chemical conditions within the vein system. However, the fluid inclusion data contrast markedly with data obtained at other Meguma gold deposits (see below; Kontak *et al.*, 1988; Kontak and Smith, 1989; and the authors' unpublished data).

The veins at West Gore occupy extentional fractures that strike perpendicular to the main folds and schistosity of the wall rock. The observation of sulphide porphyroblasts overgrowing the schistosity in wall rock fragments and projecting into unstrained, euhedral vein quartz indicates that vein formation postdated regional deformation. These relationships are consistent with observations in other Meguma gold deposits and absolute ages ($^{40}Ar/^{39}Ar$) which suggest a time of vein formation of ca. 370 Ma (Kontak *et al.*, 1990b).

The inferred physio-chemical conditions of the vein-forming fluids, as indicated by the fluid inclusions at West Gore, contrast markedly with those of other Meguma gold deposits, established by

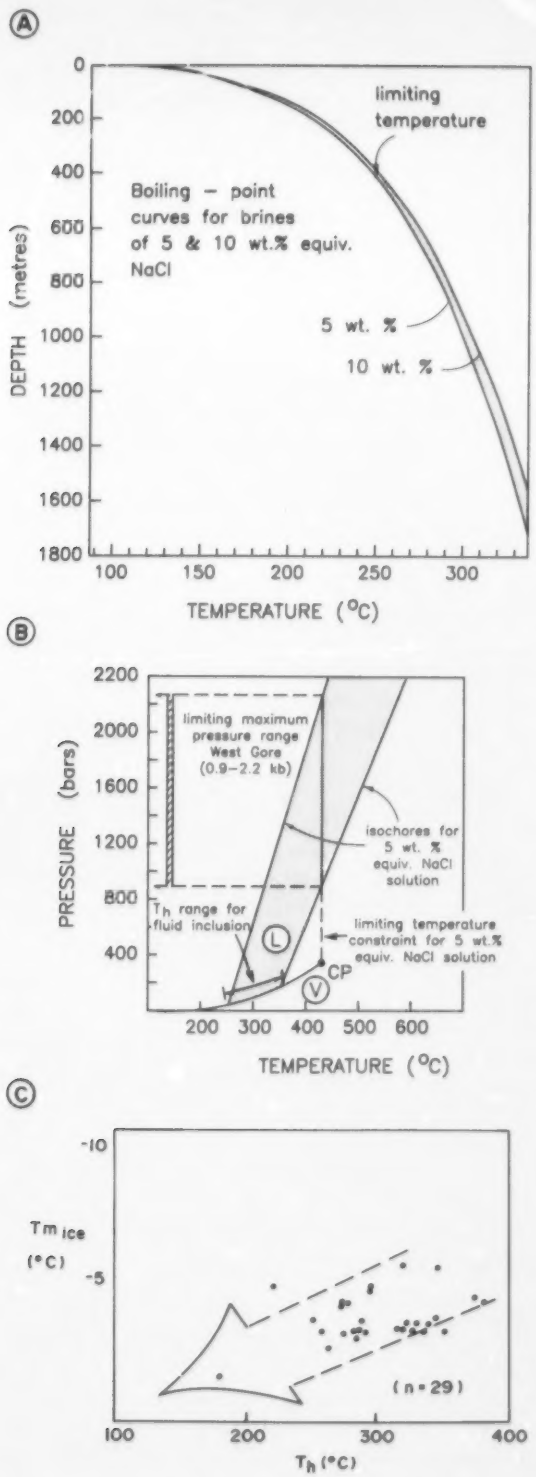

Figure 8. (a) Boiling point curve for H_2O containing 5 and 10 wt.% equivalent NaCl (after Haas, 1971). The shaded area indicates the limiting pressure for West Gore based on T_h of fluid inclusions. (b) Pressure-temperature plot for West Gore showing the two-phase boundary curve (L-V) and critical point (CP) for an aqueous fluid containing 5 wt.% NaCl and the appropriate isochores (shaded area) for the same fluid eminating from 250° and 350°C. Dashed lines indicate the limiting pressure based on fluid inclusion data. Diagram constructed using data in Roedder (1984). (c) Binary plot of last melting temperatures for ice (Tm_{ice}) versus homogenization temperatures (T_h). The significance of the trend indicated by the arrow is discussed in the text.

earlier fluid inclusion studies (Kontak *et al.*, 1988; Kontak and Smith, 1989). Significant points of departure for other Meguma gold deposits from the West Gore data include: (1) the absence of fluid unmixing, (2) the lack of correlation between salinity and homogenization temperature, (3) the overall dominance of type 3 inclusions (H_2O-CO_2), almost to the exclusion of other types, and (4) the higher inferred pressure of vein formation (i.e. 2-3 kbar). These differences clearly indicate that the fluids responsible for ore formation as West Gore reflect either a different fluid reservoir or a similar, but modified fluid compared to other Meguma gold deposits.

Given that the inferred age of mineralization at West Gore is similar to other Meguma gold deposits, then an explanation is required to accommodate the obvious differences between the West Gore Sb-Au deposit and the majority of Meguma gold deposits in which mineralized, bedding-parallel veins dominate. One possible explanation is that the West Gore deposit represents an epizonal analogue for the deeper, mesothermal-type lode gold deposits that are more typical of the Meguma Terrane. Nesbitt and Muehlenbachs (1989) have interpreted similar deposits in the Canadian Cordillera in a similar manner. Aside from the fluid inclusion data and the different ore mineral assemblage, the texture of the quartz itself (euhedral, prismatic and undeformed) differs markedly from that of typical Meguma gold deposits and it alone strongly suggests some alterative mechanism of vein formation.

If the above conclusions inferred for West Gore are correct, then they have important implications for exploration of gold deposits in the Halifax Formation. In order to further document the nature of mineralization at West Gore, future work will include stable isotope analysis to confirm or negate the possible role of meteoric water.

REFERENCES

Ahlfeld, F. and Schneider-Scherbina, A. 1964: Los yacimientos minerales y de hidrocarburos de Bolivia; Bolivia Departmento Nacionale Geologia, Bulletin 5, 388 p.

Bates, J. L. E. 1987: Gold in Nova Scotia; Nova Scotia Department of Mines and Energy, Information Series No. 13, 48 p.

Bodnar, R. J., Reynolds, T. J. and Kuehn, C. A. 1985: Fluid inclusion systematics in epithermal systems; Reviews in Economic Geology, v. 2, p. 73-98.

Boyle, R. W. 1979: The geochemistry of gold and its deposits (with a chapter on geochemical prospecting for the element); Geological Survey of Canada, Bulletin 280, 584 p.

Chatterjee, A. K. 1983: Metallogenic Map of the Province of Nova Scotia; Nova Scotia Department of Mines and Energy, scale 1:500 000.

Colvine, A. C., Andrews, A. J., Cherry, M. E., Durocher, M. E., Fyon, A. J., Lavigne, M. J., Jr., Macdonald, A. J., Marmont, S., Poulsen, K. H., Springer, J. S. and Troop, D. G. 1984: An integrated model for the origin of Archean lode gold deposits; Ontario Geological Survey, Open File Report 5524, 84 p.

Douglas, G. V. and MacDonald, H. N. 1940: Antimony at West Gore; *in* Province of Nova Scotia, Department of Mines, Annual Report on Mines 1939, Part 2, p. 37-49.

Dowling, K. and Morrison, G. 1989: Application of quartz textures to the classification of gold deposits using North Queensland examples; Economic Geology, Monograph 6, p. 342-355.

Haas, J. L. , Jr. 1971: The effect of salinity on the maximum thermal gradient of a hydrothermal system at hydrostatic pressure; Economic Geology, v. 66, p. 940-946.

Henderson, M. N. and Henderson, J. R. 1986: Constraints on the origin of gold in the Meguma Zone, Ecum Secum area, Nova Scotia; Maritime Sediments and Atlantic Geology, v. 22, p. 1-14.

Henley, R. W., Harris, R. J. and Paterson, C. J. 1976: Multistage ore genesis in the New Zealand Geosyncline, a history of post-metamorphic lode emplacement; Mineralium Deposita, v. 11, p. 100-196.

Kay, A. and Strong, D. F. 1983: Geologic and fluid controls on As-Sb-Au mineralization in the Moreton's Harbour area, Newfoundland; Economic Geology, v. 78, p. 1590-1604.

Kontak, D. J., MacDonald, D. and Smith, P. K. 1988: Fluid inclusion study of the Beaver Dam gold deposit, Meguma Terrane, Nova Scotia; *in* Mines and Minerals Branch, Report of Activities 1988, Part A, eds. D. R. MacDonald and Y. Brown; Nova Scotia Department of Mines and Energy, Report 88-3, p. 63-70.

Kontak, D. J. and Smith, P. K. 1989: Preliminary results of a fluid inclusion study of the stockwork zone vein mineralization, Caribou Deposit, Meguma Terrane, Nova Scotia; *in* Mines and Minerals Branch, Report of Activities 1989, Part A, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Mines and Energy, Report 89-3, p. 65-70.

Kontak, D. J., Smith, P. K., Kerrich, R. and Williams, P. F. 1990a: Integrated model for Meguma Group lode gold deposits, Nova Scotia, Canada; Geology, v. 18, p. 238-242.

Kontak, D. J., Smith, P. K., Reynolds, P. H. and Taylor, K. 1990b: Geological and $^{40}Ar/^{39}Ar$ geochronological constraints on the timing of quartz vein formation in Meguma Group lode-gold deposits, Nova Scotia; Atlantic Geology, v. 26, p. 201-227.

Madu, B. E., Nesbitt, B. E. and Muehlenbachs, K. 1990: A mesothermal gold-stibnite-quartz vein occurrence in the Canadian Cordillera; Economic Geology, v. 85, p. 1260-1268.

Malcolm, N. 1929: Gold fields of Nova Scotia; Geological Survey of Canada, Memoir No. 156, 253 p.

Messervey, J. P. 1932: Antimony in Nova Scotia; Nova Scotia Department of Public Works and Mines, Pamphlet 1, 23 p.

Morrissy, C. J. and Ruitenberg, A. A. 1980: Geology of the Lake George antimony deposit, southern New Brunswick; Canadian Institute of Mining and Metallurgy, v. 73, no. 822, p. 79-84.

Nesbitt, B. E. and Muehlenbachs, K. 1989: Geology, geochemistry, and genesis of mesothermal lode gold deposits of the Canadian Cordillera: evidence for ore formation from evolved meteoric water; Economic Geology, v. 82, p. 553-563.

O'Shea, P. J. and Pertzel, B. A. 1988: The Brunswick gold-antimony mine, Costerfield, Victoria; Geological Society of Australia, Abstract Series, no. 23, p. 282-284.

Paterson, C. J. 1982: Oxygen isotopic evidence for the origin and evolution of a scheelite ore-forming fluid, Glenorchy, New Zealand; Economic Geology, v. 77, p. 1672-1687.

Paterson, C. J. 1986: Controls on gold and tungsten mineralization in metamorphic - hydrothermal systems, Otago, New Zealand; Geological Association of Canada, Special Paper 32, p. 25-39.

Ramdohr, P. 1980: The Ore Minerals and Their Intergrowths; Second Edition, Pergamon Press, New York, 1205 p.

Roedder, E. 1984: Fluid Inclusions; Mineralogical Society of America, Reviews in Mineralogy, v. 12, 644 p.

Seal, R. R., II, Clark, A. H. and Morrissy, C. J. 1987: Stockwork tungsten (scheelite)-molybdenum mineralization, Lake George, southwestern New Brunswick; Economic Geology, v. 82, p. 1259-1282.

Steed G. M. and Morris, J. H. 1986: Gold mineralization in Ordovician greywackes at Clontibret, Ireland; Geological Association of Canada, Special Paper 32, p. 67-86.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 75

SEISMIC INTERPRETATION, POTENTIAL OVERTHRUST GEOLOGY AND MINERAL DEPOSITS IN THE KENNETCOOK BASIN, NOVA SCOTIA[1]

R. C. Boehner

The occurrence of thrust faults with a range of magnitudes and associations has been reported at various localities in Carboniferous basins, including the Kennetcook Basin area adjacent to the Cobequid-Chedabucto Fault System (CCFS) and the Fundy Rift. Although the inferred relationship between tectonics and metallogenesis in the basins is controversial, it would be important both for the genesis of mineral deposits and their subsequent disruption. The structural geology of the Kennetcook Basin is complex and appears to be compatible with restraining-convergence tectonics on subsidiary faults related to dextral east-west strike slip motion on the CCFS. Superposition of the Fundy Rift in a later extensional environment has further complicated the interpretation of the structural history.

Evidence for overthrusting has been previously restricted to small scale thrust fault occurrences (tens of metres) reported near the western extremity of the Kennetcook Basin. Reflection seismic survey lines across the basin near Kennetcook and Noel by Soquip *et al.*, together with deep and shallow exploration drillholes, permit the definition of the gross basin configuration. Interpretation of large scale features of the seismic lines indicates the southeast border of the basin is a major high angle fault (2300 m dip slip) and the north border appears to be a southward overthrust of deformed Horton Group and basal Windsor Group rocks (together with numerous mineral occurrences). The concept that post-mineralization overthrusting along the northwest border of the basin (Walton Belt) may have concealed significant Cu-Pb-Zn-Ag-Ba deposits is intriguing. Exploration strategies and techniques in this environment would necessarily be indirect, innovative and expensive (including high resolution seismic surveys). Depth, exploration expense and historical mining problems are obvious major challenges.

1 Poster presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991; see more complete details in paper by the same title and author, this volume

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 76

U-TH-PB SYSTEMATICS OF THE SOUTH MOUNTAIN BATHOLITH, NOVA SCOTIA[1]

A. K. Chatterjee and L. J. Ham

Elemental concentrations of U, Th and Pb, and Pb isotopic compositions for 34 samples were determined to assess the age, mobility of elements and source rock reservoirs for the peraluminous granitoids of the South Mountain Batholith. The concentrations (ppm) of U, Th and Pb range from 1.510 - 28.780, 1.483 - 18.403 and 2.25 - 24.87, respectively, and the measured $^{206, 207, 208}Pb/^{204}Pb$ isotopic ratios range from 18.627 - 51.945, 15.621 - 17.422 and 38,319 - 42.625, respectively. Whole-rock and mineral separates from a granodiorite and a sample of leucogranite from two different plutons within the batholith were analyzed isotopically to constrain age of the least- and most-evolved phases of the body. The granodiorite yields a Pb-Pb age of 373.3±3.6 (MSWD 2.85, 2 sigma) and the leucogranite yields a Pb-Pb age of 365.2±5.4 (MSWD 2.57,2 sigma). Both ages are considered, within the limits of error, to be identical to the Rb-Sr whole-rock age of 371.8±2.2 Ma for the batholith (Clarke and Halliday, 1980).

Regression of the Pb-Pb data intersects the Pb growth curve to give $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ ratio values of 18.143 - 18.139 and 15.601 - 15.600, respectively. These values are close to isotopic values of galena from a granodiorite (18.141, 15.603, 38.209 for $^{206, 207, 208}Pb/^{204}Pb$, respectively). Thus, the initial composition of lead at the time of emplacement of the batholith was close to the compositions of galena.

The whole-rock isotopic data, when corrected for common lead, plot on a $^{206}Pb/^{238}U$-$^{207}Pb/^{235}U$ diagram and intersect the concordia at near zero and 369 Ma (2 sigma). The distribution of points on the concordia diagram is interpreted to reflect loss of uranium during the post-magmatic stage (i.e. a lost of volatiles). Isotopic data in these uranium-lead and thorium-lead diagrams suggest that uranium has been relatively immobile since the time of intrusion and that the apparent Th/U ratios were generated as part of the magmatic evolution.

Isotopic data ($^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$), corrected to the age of intrusion, yield a linear array, interpreted to be a secondary isochron which we interpret to represent the age of the protolith (669±131 Ma). Potential protoliths include Meguma Group metasedimentary rocks, Liscomb gneissic rocks and Tangier metasedimentary and mafic granulite, but the granulite cannot accommodate the total range of the $^{206}Pb/^{204}Pb$. We suggest that the magma for the South Mountain Batholith is granulite-derived and contaminated with Liscomb gneiss (with minor contribution from Meguma Group rocks) prior to crystallization.

1 Presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 77

VARIATIONS IN LIL ELEMENTS, HFS ELEMENTS AND REEs WITHIN THE DAVIS LAKE PLUTON, SOUTHWESTERN NOVA SCOTIA[1]

A. K. Chatterjee and R. J. Horne

The Davis Lake Pluton is a large (816 km^2), tilted, mushroom-shaped intrusion occupying the southwestern end of the South Mountain Batholith. Coarse grained monzogranite is the dominant lithology of the pluton with minor fine- to medium-grained leucomonzogranite (2-6% mafic minerals) and leucogranite (<2% mafic minerals) exposed in the westernmost lobe along the contact with Lower Paleozoic metasedimentary rocks of the Meguma Group.

The Davis Lake Pluton displays pronounced continuous and discontinuous cryptic chemical zonation. For example, the K/Rb ratio shows continuous variation from >200 to <50. Present-day measured whole-rock uranogenic lead isotopic ratios and ΣREEs show similar variation, with the least evolved rocks of the pluton (K/Rb from 204 to 244) having ΣREEs ranging from 143 to 212 and $^{206}Pb/^{204}Pb$ ratios between 18.627 and 18.884, and the most evolved rocks (K/Rb ratios <50) having ΣREEs ranging from 22 to 48 and $^{206}Pb/^{204}Pb$ ratios ranging from 27.742 to 51.945. Elemental pairs such as Zr-Ta, Ti-Zr and K/Rb-Rb/Sr ratios show continuous co-variation. Marked discontinuity is shown by other elements such as Y, Th and Nb, and also $^{206}Pb/^{204}Pb$ isotopic ratios. Spatial discontinuities occur in a zone which is characterized by granitoid rocks with a K/Rb ratio between 50 and 100.

The distinctive geochemical trends are recognized in some of the data such that two groupings are made: group 1 is characterized by ΣREEs from 66 to 152 ppm (x=111) and $(La/Yb)_n$ ratios from 1.71 to 2.74 ppm (x=2.23), whereas group 2 is characterized by ΣREEs from 40 to 75 ppm (x=55) and $(La/Yb)\ N_n$ ratios from 4.00 to 8.08 (x=5.28).

The regional chemical and isotopic variations within the DLP cannot be explained by assimilation/fractional crystallization of a single magma or subsequent deformation and attending hydrothermal alteration of the pre-existing rocks. The most plausible explanation for the observed variation is the presence of two distinct peraluminous magmas derived from a heterogeneous source region.

1 Presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 78

CONTRASTING GREISENS AND ASSOCIATED GRANITOID ROCKS OF THE DAVIS LAKE PLUTON: IMPLICATIONS FOR THE ORIGIN OF THE EAST KEMPTVILLE TIN DEPOSIT, NOVA SCOTIA[1]

A. K. Chatterjee and M. A. MacDonald

Muscovite-rich (K_2O-3.21-4.33 wt%) polymetallic quartz-topaz greisens (0.16-1.78% Sn) at the East Kemptville tin deposit, and other greisen veins hosted within the leucogranites of the Davis Lake Pluton, are characterized by low K/Rb (<50), high Rb/Sr (>84) and high average concentrations of F (1.6%), Li (830 ppm) and Rb (1060 ppm). Published analyses of the greisens together with the present data define two distinct U-enrichment trends in the U-Th-Y ternary system. The two trends are essentially due to different Th/U and Th/Y ratios with similar but changing U/Y ratio. The concentration of 14 REEs and $(La/Yb)_N$ ratios for the greisens and associated granitoids also show two distinct groupings for each rock type. Two distinct trends are also recognized for greisen, leucogranite and leucomonzogranite in the $^{208}Pb/^{204}Pb$ vs $^{208}Pb/^{204}Pb$ diagram. However, linear variations in $^{208}Pb/^{204}Pb$ vs $^{232}Th/^{204}Pb$ and $^{238}U/^{204}Pb$ vs $^{206}Pb/^{204}Pb$ diagrams imply immobility of U,Th and Pb since the time of crystallization and greisenization.

The most significant feature of the data set is the remarkable collinearity in the $^{206}Pb/^{204}Pb$ vs $^{207}Pb/^{204}Pb$ diagram for the greisens and associated leucogranitoids. Greisens from both trends define a slope of 0.053872 (S.D. 0.000065) and a corresponding age of 365.7±2.7 Ma (MSWD 1.95, 2 sigma). The combination of leucogranite and greisen together defines a slope of 0.053879 (S.D. 0.000066) corresponding to an age of 366.0±5.6 Ma (MSWD 1.79, 2 sigma). We conclude that greisen and leucogranite are of similar ages and are not 40 Ma younger than the remainder of the South Mountain Batholith as previously suggested. We argue that separate greisen fluids were probably derived from two distinct peraluminous magmas, derived from a heterogeneous source, and that the East Kemptville tin deposit probably owes its origin to mixing of these fluids under post-magmatic conditions. The heterogeneous source for the Davis Lake Pluton magma(s) was probably characterized by a significantly higher $^{238}U/^{204}Pb$ ratio than the average orogene.

1 Presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 79

POTENTIAL SOURCE ROCKS FOR GOLD IN MEGUMA-HOSTED AURIFEROUS VEIN DEPOSITS, NOVA SCOTIA[1]

A. K. Chatterjee and P. K. Smith

Initial Sr (carbonate) and Pb (galena) isotopic ratios from auriferous vein deposits hosted in Cambro-Ordovician Meguma Group rocks provide constraints regarding origin and potential metal source in the deposits. The Sr_i of carbonates ranges from 0.7079 to 0.7156 and $^{206, 207, 208}Pb/^{204}Pb$ values for galena range from 17.191 - 18.568, 15.483 - 15.643 and 36.767 - 38,309, respectively. Large variations in radiogenic isotopes are present within individual deposits (e.g. Moose River, Goldenville). The observed variations and radiogenic tendencies cannot be attributed to stratigraphic position or proximity to exposed intrusions. The ranges of calculated Sr_i and $^{206}Pb/^{204}Pb$ at 372 Ma for various groups of metamorphic and intrusive rocks are given in Table 1. It is clear that neither the Meguma Group alone nor any combination of Meguma Group medisedimentary rocks and Devono-Carboniferous intrusions can accommodate the range of observed initial Sr and Pb isotopic ratios in the vein deposits. Alternatively, the Liscomb gneiss could potentially be the sole source for the observed ratios and, hence, also for the hydrothermal fluids from which the quartz veins formed. In summary, these isotopic data indicate that the Meguma Group can be eliminated as the sole source of the auriferous veins via a metamorphogenic model and that a fluid/metal source within the Liscomb gneissic rocks is more probable.

Table 1. Ranges of calculated Sr_i and $^{206}Pb/^{204}Pb$ for various rock groups.

	$^{87}Sr/^{86}Sr$ $IR_{t=372\ Ma}$	$^{206}Pb/^{204}Pb$ $IR_{t=372\ Ma}$
Gold Deposits (N=20)	0.7079 - 0.7156	17.191 - 18.568
Meguma Group (N=12)	0.7113 - 0.7177	17.632 - 18.277
Liscomb gneiss (N=10)	0.7060 - 0.7165	16.365 - 18.506
Felsic sed. granulite (N=17)	0.7046 - 0.7088	18.507 - 18.954
Mafic granulite (N=11)	0.7028 - 0.7051	18.124 - 19.194
SMB:Magmatic (N=21)	0.7076 - 0.7094	18.141 - 19.154
Liscomb granite (N=3)	0.7080 - 0.7090	18.411 - 18.435
Liscomb mafic intrusions (N=7)	0.7031 - 0.7078	17.599 - 18.566
Lamprophyre dyke, Tangier (N=3)	0.6994 - 0.7067	18.334 - 18.771

1 Presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 80

CHARACTERISTICS OF REE AND OTHER TRACE ELEMENTS IN RESPONSE TO SUCCESSIVE AND SUPERIMPOSED METASOMATISM WITHIN A PORTION OF THE SOUTH MOUNTAIN BATHOLITH, NOVA SCOTIA, CANADA[1]

M. C. Corey and A. K. Chatterjee

Successive and superimposed periods of late- to post-magmatic metasomatism have resulted in mineralogical and textural modification within (leuco) monzogranite rocks of the Big Indian Lake Polyphase Intrusive Suite (BIPIS). The alteration and associated mineralization exhibit a transition from an early pervasive style to a later fracture-controlled style, and can be defined by diagnostic REE and other trace-element behavior. While the anomalous behavior of some elements (MnO, Ta, U, K/Rb, HREE) is attributed to metasomatic-hydrothermal activity, the compatible behavior of B, F, Li, W and Rb appears to have been governed by predominately magmatic processes. All elements including Al can be mobilized during repeated fluid-rock interaction. The behavior of REE during evolution of the BIPIS indicates that they also were affected by both magmatic (LREE depletion, Eu depletion) and metasomatic (HREE, LREE enrichment, Eu enrichment/depletion) processes. The remobilization and subsequent redeposition of trace elements is dependent upon the nature and stability of the metasomatic mineral assemblages. In this respect, a metasomatized granitic rock could reflect a REE pattern similar to that of an unaltered equivalent.

1 In: Chemical Geology, v. 85, p. 265-285

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 81

SEISMIC IDENTIFICATION OF POROSITY IN JURASSIC CARBONATE, OFFSHORE NOVA SCOTIA[1]

P. J. Harvey

Porous reservoirs have been identified in five wells that have penetrated Nova Scotia's Jurassic carbonate bank. Geophysical modelling clearly shows that porous dolomites can be detected in one of these wells, the Shell Demascota G-32 well. Amplitude-versus-offset (AVO) models were also studied in the Demascota area and indicate that increasing amplitude with offset should be associated with these fractured, porous, gas-filled dolomite reservoirs.

The interpretation of two conventional processed seismic lines through the Demascota well identified an anomalously bright reflection within the Baccaro Member. This reflection ties a porous interval within the carbonate bank. Due to multiples and the close proximity of these porous dolomites to the bank edge, their detection on real data will prove to be a challenge to both processor and interpreter.

Two seismic lines were reprocessed in an effort to retain relative amplitudes so that AVO changes on actual data could be compared with those observed from modelling. Since the initial gathers were uninterpretable for AVO changes, the discrete Radon transform filter was used to produce interpretable offset displays.

Interpretation of AVO changes on both lines match the seismic models well. The two seismic lines display AVO anomalies which exhibit an increase in amplitude with offset distance and are well situated to be interpreted as fractured, porous, gas-filled dolomites.

Although AVO is in its infancy offshore Nova Scotia, these studies have confirmed that the AVO tool may provide assistance in predicting and mapping these zones.

1 Presented at Society of Exploration Geophysicists (60th annual meeting and exposition), September 25, 1990, San Francisco, California

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 82

FLUORESCENCE PROPERTIES OF ALGINITE-RICH OIL SHALES FROM THE STELLARTON BASIN, CANADA[1]

W. Kalkreuth[2], R. Naylor, K. Pratt[2] and W. Smith

Oil shale beds from the Stellarton Basin, Nova Scotia, were characterized using macroscopic and microscopic fluorescence properties of the organic material and by Rock-Eval analysis techniques. Results from image analyses show that the distinct fluorescing layering observed when the rocks were irradiated with ultraviolet light is related to differences in alginite contents contained in the oil shales. Comparison with Rock-Eval analyses shows that total organic carbon contents and oil and gas potentials correlate well with microscopically determined alginite contents. Macroscopic examination of oil shale beds during ultraviolet excitation may thus be used as a fast screening method to assess oil shale quality.

1 In: Fuel, 1990, v. 69, February
2 Institute of Sedimentary and Petroleum Geology, 3303-33rd St. N. W., Calgary, Alberta T2L 2A7, Canada

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 83

LITHOPROBE EAST MARINE DEEP SEISMIC REFLECTION DATA, BAY OF FUNDY AND THE GULF OF MAINE: PRE-PRELIMINARY INTERPRETATION[1]

C. E. Keen[2], W. Kay[2], J. D. Keppie, F. Marillier[3], B. McLean[4], G. Pe-Piper[5], G. S. Stockmal[6] and J. W. F. Waldron[7]

Approximately 210 km of marine deep seismic reflection data were gathered in the Gulf of Maine and across the Bay of Fundy in 1988. These data were collected to 20-24 s two-way time, equal to 50-60 km depth at a seismic velocity of 5 km/s. The lines were positioned to cross-cut and parallel the regional structural grain in the Meguma zone and thus compliment the 1986 and 1984 data sets gathered in the Gulf of St. Lawrence and north of Newfoundland.

A number of features are clearly imaged, including: the Fundy graben bounding fault, which may flatten abruptly at mid crustal depth; a strongly layered lower crust, which is divisible into two discrete packages SE of Passamaquoddy Bay; and a shallowing dipping set of reflectors which appear to cross-cut the Moho SW of Yarmouth.

The interpretation of this data set is in a preliminary stage only. Therefore, we are not offering a complete story. Rather, we are displaying the data set as well as line drawings made from the seismic records to prompt feedback from the general AGS membership.

1 In: Atlantic Geoscience Society Abstracts, 1990 Symposium on New Age Determinations in the Atlantic Provinces; Atlantic Geology, v. 26, p. 174-175

2 Geological Survey of Canada, Atlantic Geoscience Centre, P. O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2
3 Geological Survey of Canada, Atlantic Geoscience Centre, P. O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2
4 Institute of Sedimentary and Petroleum Geology, 3303-33rd Street NW, Calgary, Alberta T2L 2A7
5 Department of Geology, St. Mary's University, Halifax, Nova Scotia B3H 3C3
6 Geological Survey of Canada, Atlantic Geoscience Centre, P. O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2
7 Department of Geology, St. Mary's University, Halifax, Nova Scotia B3H 3C3

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 84-87

INTRODUCTION TO TERRANE ANALYSIS AND THE TECTONIC MAP OF PRE-MESOZOIC TERRANES IN CIRCUM-ATLANTIC PHANEROZOIC OROGENS[1]

J. D. Keppie and R. D. Dallmeyer[2]

Terrane terminology and its definition originated in the North American Cordillera. However, the Cordillera represents a special case in a wide spectrum of accretionary terrane orogens in which factors such as:

(1) the relative motions between terranes may vary from orthogonal to highly oblique (exotic terranes) - where terranes originate and are accreted by orthogonal relative motions, neighbouring terranes may have similar geological records (proximal terranes) and may only be distinguished by the nature of the suture boundary, which represents telescoped oceanic lithosphere;

(2) the stage of convergence may vary from simple ocean-continent convergence through magmatic arc-continent collision; and

(3) the depth of erosion may vary, which relates to the tectonothermal state of the rocks exposed at the surface and the age of the orogen.

The Cordillera may represent an end member in the high degree of obliquity of the convergence producing exotic terranes, and in the limited amount of erosion. The deeper the level of erosion, the more the identification of terranes moves from stratigraphic/paleontological/ paleomagnetic criteria to metamorphic/structural/petrological/metallogenic/geophysical properties. This requires modification of the original terrane definition, viz.

A TERRANE IS REDEFINED AS AN AREA CHARACTERIZED BY AN INTERNAL CONTINUITY OF GEOLOGY (including stratigraphy, fauna, structure, metamorphism, igneous petrology, metallogeny, geophysical properties, and paleomagnetic record) THAT IS BOUNDED BY FAULTS OR MELANGES REPRESENTING A TRENCH COMPLEX, OR A CRYPTIC SUTURE ACROSS WHICH NEIGHBOURING TERRANES MAY HAVE A DISTINCT GEOLOGICAL RECORD NOT EXPLICABLE BY FACIES CHANGES (I.E. EXOTIC TERRANES), OR MAY HAVE A SIMILAR GEOLOGICAL RECORD (I.E. PROXIMAL TERRANES) THAT MAY ONLY BE DISTINGUISHED BY THE PRESENCE OF THE TERRANE BOUNDARY REPRESENTING TELESCOPED OCEANIC LITHOSPHERE.

In applying this definition, it is essential that rock units of the same age be compared and that facies changes be eliminated as an explanation for different properties. As terrane concepts gained in popularity, examples have proliferated where terranes have been defined by comparing rock units of different ages (with distinct properties) or by ignoring the possibilities of facies changes. As a reaction to this approach, others have drawn attention to the similarites of units ignoring an intervening suture and have argued against the existence of terranes. Where neighbouring areas of the same age are distinct but facies changes cannot be eliminated at the present stage of knowledge, the conservative approach is to define them as "suspect terranes" until such time as they are proven to be true terranes or acquitted. This calls for careful application of the terrane definition bearing in mind the limitations inheritant in the use of each property. Limitations in the application of each property are outlined below.

---

1 In: Abstracts from Terranes in the Circum-Atlantic Paleozoic Orogens; International Conference on Paleozoic Orogens in Central Europe, Gottingen-Gissen, Germany, August - September 1990; International Geological Correlation Program 233

2 Dept. of Geology, University of Georgia, Athens, Georgia, U. S. A. 30602

STRATIGRAPHY. Distinct stratigraphies of the same age may be separated by a fault and yet be merely displaced portions of the same sedimentary environment, e.g. continental shelf; and the fault does not represent a suture. Clearly these distinct stratigraphies represent facies equivalents in a palinspastic reconstruction. Continental rise and miogeoclinal rocks are facies equivalents of one another; however, in some cases they are now separated by a fault and with the present state of knowledge it is impossible to show that they were formerly transitional into each other - in this case they may be termed "suspect terranes" until further work clarifies their relationships. On the other hand, the stratigraphic record of two areas may be very similar, for example two ocean floor sequences or oceanic platforms in the Pacific and Indian Oceans, and yet they are separated by a trench complex and so are separate terranes. Similarly two magmatic arc terranes may be separated by a trench and yet consist of very similar stratigraphic sequences.

PALEONTOLOGY. Faunal provinces are the most commonly used property in defining terranes; however, where these are controlled by environmental factors such as water depth or temperature, there is no a *priori* reason why they should coincide with terrane boundaries. This is especially the case for pelagic fauna, which may migrate onto the surrounding shelves with changes in water depth or currents. Thus, faunal provinces may alternate in one stratigraphic sequence in one terrane. Most useful are shallow marine or continental fauna that cannot migrate across deep, wide oceans. In application, such distinctions are very broad, and only add to the identification of terranes using other criteria.

PALEOMAGNETIC DATA. In general paleomagnetic data are most easily interpreted in stratified rocks that have suffered little or no tectonothermal effects. These conditions most often occur in relatively large terranes peripheral to the accretionary orogen and rarely within the orogen. Most terranes have suffered considerable deformation and this requires a thorough knowledge of the structural geology in order to subtract its effects. Metamorphism progressively modifies the paleomagnetic record and may make it difficult to identify the original signature. Chemical alteration has similar effects. Paleomagnetic data from plutons are of little use if the paleohorizontal is unknown. Paleomagnetic data that yield contrasts in paleolatitude are most amenable to terrane analysis. Rocks with similar paleolatitudes may or may not be separated by a suture. Differences in declination may add evidence to terrane identification using other properties.

METAMORPHISM. Most metamorphism post-dates docking of terranes and so adds little to terrane identification. Thus, contrasts between metamorphic assemblages generally relate to facies changes. In metamorphic rocks, it is necessary to subtract the effects of metamorphism to derive the protoliths which may then be analyzed by stratigraphic criteria. High pressure - low temperature metamorphism is often associated with subduction zones and trench complexes, and if so can be used to define terrane boundaries. Contrasts in pre-docking metamorphism may add to terrane identification.

STRUCTURE. Most structural deformation is associated with docking and subsequent accretionary deformation and in this case is of little use in terrane identification. Terrane boundaries are faults, trench complexes and/or cryptic sutures and so outline terranes. Pre-docking deformation may aid in the identification of terranes.

IGNEOUS PETROLOGY. Igneous rocks may be divided into pre- and post-docking, and only the former may be used for terrane identification. Igneous rocks reflect their source regions and so there may only be a tenuous connection between them and the country rocks. Incongruous tectonic settings may add to the identification of terranes, but chemical affinities (calcalkaline-tholeiitic-alkaline) may or may not be facies equivalents.

METALLOGENY. Metallogenic data may also be divided into pre- and post-docking stages and onlt the former are useful for terrane identification. Syngenetic mineralization may be applied to terrane identification most easily because other types of mineralization often have a complex genesis. Contrasting mineralization may or may not be due to mineral zoning, i.e. facies equivalents.

GEOPHYSICAL PROPERTIES. Geophysical properties - magnetic, gravity, seismic - may be used to trace terranes and terrane boundaries once they are defined by other properties and only when the boundary has a geophysical expression. This requires that the near-surface geophysical data be separated and analyzed spatially with respect to a terrane map and where correlations are found these may be extrapolated beneath overstep sequences and to depth. Care must be exercised where similar geophysical anomolies attributable to different causes merge, and where the geophysical properties within one terrane change due to facies changes in the geological properties. It is generally difficult to uniquely identify deep geophysical properties with terranes or terranes boundaries.

Terrane mapping has progressed from merely outlining the terranes to those depicting their tectonic settings. The Tectonic Map of Pre-Mesozoic Terranes in Circum-Atlantic Phanerozoic Orogens depicts Precambrian-Paleozoic terranes within circum-Atlantic Phanerozoic orogens on a Permian palinspastic reconstruction, i.e. a closed Atlantic Ocean. The base map is a transverse Mercator projection with the Equator along the axis of the closed Atiantic. The terranes are categorized by age and tectonic setting: autochthonous and imbricated basement/miogeocline, continental rise, oceanic lithosphere, oceanic sedimentary/volcanic sequence, volcanic/magmatic arc complex, intra-arc basin, periarc basin, trench complex, disrupted terrane (tectonic melange), metamorphic rocks of uncertain protolith, continental rocks of uncertain affinity, and continental rift rocks of uncertain affinity. Most oceanic terranes appear to represent small ocean basins rather than fragments of the main oceans. Also shown are post-accretionary stitching plutons, overstep sequences and accretionary diagrams for various sections of the orogens. The accretionary diagrams depict the rocks types and their inferred tectonic settings, the time of docking and the sense of pre- and post-accretionary movements, stitching plutons and overstep sequences.

The major cratonic terranes and their miogeoclines around the margins of the circum-Atlantic Paleozoic orogens are structurally separated from the magmatic arc and oceanic terranes, which occur in the internal and uppermost structural parts of the various orogens. Disrupted terranes, mainly consisting of blocks of ophiolite, oceanic and periarc rocks set in a foliated matrix of miogeoclinal and continental rise affinities, generally occur along the margins of the major cratonic terranes. Precambrian rocks in the major cratonic terranes bordering the circum-Atlantic Phanerozoic Orogens show a wide range of age: Archean, Early Proterozoic and Middle Proterozoic (Grenvillian) occur in Baltica, Laurentia and South America -- Grenvillian is absent in north-western Africa. Continental terranes with Archean-Proterozoic basement are scattered throughout the circum-Atlantic Phanerozoic orogens; however, the widespread distribution of such rocks in the surrounding major cratonic terranes indicates that the age of the basement alone is not a unique feature for distinguishing kinship. The Late Precambrian terranes are limited to the southeastern part of the map: central/western Europe, southern British Isles, southeastern Appalachians, northwest Africa and northern South America; and were accreted in Late Precambrian - Cambrian orogens. These latter orogens were developed across Precambrian rocks ranging from Archean to Middle Proterozoic and their accretional activity overlapped the time span for the opening of Iapetus, suggesting that they originated in a separate ocean. Magmatic arc and periarc terranes are well preserved in some of the Late Precambrian - Cambrian orogens in contrast to their poor representation in the Paleozoic orogens. As magmatic arcs lie on the upper plate, they would probably be removed by erosion following continental collision. Thus, their preservation in the Late Precambrian - Cambrian orogens suggests that such collisions did not occur. Overstep sequences across the Late Precambrian terranes may become miogeocline relative to the Phanerozoic orogens. Most of the identified Paleozoic, ophiolitic, magmatic arc and oceanic terranes in the circum-Atlantic Phanerozoic orogens appear to have formed during the Cambro-Ordovician, with relatively few such terranes of Silurian-Carboniferous age occurring mainly in western and central Europe. This suggests that Iapetus was essentially closed by the end of the Early Paleozoic. This is supported by the presence of distinct faunal provinces in the Cambro-Ordovician followed by a cosmopolitan fauna in the Siluro-Devonian. Late Paleozoic orogenic activity is inferred to be mainly transpressive along the vestiges of Iapetus, while convergence was still taking place in the Variscan orogen. The scale of Late Paleozoic transcurrent and rotational movements is presently uncertain and several widely divergent models based upon paleomagnetic data are current.

The accretionary history of pre-Mesozoic terranes in Circum-Atlantic Phanerozoic orogens may be broadly divided into:

(1) terranes located in northwestern Africa, central/western Europe, southern British Isles, southeastern Appalachians and northern South America, which were accreted during the latest Proterozoic-Cambrian during the Pan African-Cadomian Orogeny;

(2) terranes located in the Appalachians, the Caledonides of Greenland, Svalbard, Scandinavia and the British Isles, and the Variscides of central/western Europe and northwest Africa, which were mainly accreted during the Early Paleozoic with a few accretionary events occurring in the Devono-Carboniferous (mainly in the Variscides);

(3) terranes located in the Alpine and Andean orogens many of which still retain evidence of their Late Paleozoic overstep sequence.

Some terranes have suffered a poly-orogenic history involving alternating accretion and dispersion. Palinspastic models for Precambrian-Early Paleozoic are presently poorly constrained by paleomagnetic data. However, the following tentative model may be proposed when paleomagnetic data are combined with paleontological and tectonic data from the map of pre-Mesozoic terranes in circum-Atlantic Phanerozoic orogens:

(a) latest Proterozoic-Cambrian separation of South America and Baltica from Laurentia is constrained by contemporaneous passive margin sequences and took place concurrently with convergence along an ocean-continent (±island arcs) boundary in Pan-African orogens along the northern margin of Africa and South America;

(b) Ordovician-Silurian sinistral convergence of Baltica and Gondwana (?South America) with Laurentia ended with the virtual elimination of Iapetus as constrained by the presence of similar, Late Silurian freshwater vertebrates on both Baltica and Laurentia and Early Devonian, Eastern Americas brachiopod Faunal Realm in Laurentia and northern South America;

(c) Devono-Carboniferous dextral convergence across the Variscides and the Appalachians may be related to anticlockwise rotation of Gondwana relative to Laurentia.

Within this general scenario, the geological record of individual terranes provides some constraints upon their origin. The terrane map provides the base for other thematic maps, showing metamorphic and structural data, for example.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 88

DETRITAL ZIRCON AGES FROM THE LATE PRECAMBRIAN CONGLOMERATE, AVALON COMPOSITE TERRANE, ANTIGONISH HIGHLANDS, NOVA SCOTIA[1]

J. D. Keppie and T. E. Krogh[2]

Individual, detrital zircons separated from a conglomerate in the Livingstone Cove Formation yielded the following U-Pb data (2 sigma analytical uncertainties = ± 4 to 6 Ma):

Number of grains & type	Pb/Pb age Ma	% discordance
4 euhedral & colourless	613 & 616	0.2-0.5%
2 euhedral & colourless	622 & 624	<1%
1 rounded & brown	1009	<1%
1 rounded & colourless	1160	<1%
2 rounded, euhedral & pink	1171 & 1216	<1%
2 rounded, euhedral & pink	1522 & 1546	1% & 1.4%
1 rounded, euhedral & pink	1835	1.5%
2 rounded, euhedral & pink	1955 & 1995	1% & 3%
1 rounded sphere & pink	2606	6%

The Livingstone Cove Formation is the middle unit of the Late Proterozoic Georgeville Group - an intra-arc basin deposit within the Avalon, cratonic, magmatic arc terrane. The 610-625 Ma old zircons are inferred to have been derived from this magmatic arc while the 1-1.2 Ga zircons probably came from its continental basement that is exposed in northwestern Cape Breton Island (previously dated at 1172+135/-73 Ma and 918+78/-179 Ma, U-Pb cord). The source of the older zircons is also inferred to be in the magmatic arc basement; however, a multistage sedimentary transport history cannot be ruled out. The near concordance of the 1520-1550 Ma, 1835 Ma and 1950-2000 Ma ages suggests that tectonothermal events took place at these times.

1 In: 1990 Abstracts with Programs; 25th Annual Meeting, Northeastern Section, Geological Society of America, March 1990, Syracuse, New York; Geological Society of America, v. 22, no. 2, p. 27-28

2 Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada M5S 2C6

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 89-90

U-PB ISOTOPIC DATA FROM NOVA SCOTIA: CLUES FOR ESTABLISHING TERRANE LINKAGES[1]

J. D. Keppie and T. E. Krogh[2]

U-Pb dating of detrital zircon, monazite and titanite, and igneous zircon with inherited cores may yield information germain to establishing terrane linkages. Thus, ages of detritus may be compared with ages in neighbouring potential source terranes to establish the time of juxtaposition. Ages that predate docking may be used to correlate with potential sources that may have been tectonically removed from the immediate vicinity and may help in palinspastic reconstructions. The ages of cores from igneous zircons can be used to derive the age of the magma source. In orogens where terranes are thrust over one another, resulting in depression of the lower crust followed by a slow rise of the isotherms leading to plutonism, the ages of zircon cores may help in the identification of the underthrust terrane and give an upper limit on the time of docking. Examples of this use of U-Pb data in Nova Scotia are presented.

Individual, detrital zircons have been separated from (1) a Late Proterozoic conglomerate in the Livingstone Cove Formation in the Avalon Composite Terrane and (2) two (?)Cambrian greywackes from the Goldenville Formation in the Meguma Terrane of Nova Scotia. They yielded the following U-Pb data:

AVALON COMPOSITE TERRANE, LATE PRE-CAMBRIAN LIVINGSTONE COVE FM		MEGUMA TERRANE (?)CAMBRIAN GOLDENVILLE FM	
Pb/Pb age Ma	Source	Pb/Pb age Ma	Source
613 & 616 ± 5	Igneous	562 ± 5(t) & 556 ± 6(z)	Igneous-Metam
622 & 624 ± 5	Igneous	605, 632, 643, & 647-675	Igneous
1009 ± 5			
1160 ± 5			
1171 & 1216			
1522 & 1546			
1955 & 1995		2040, 2059, & 2083	Igneous-Metam
1835		2140	Igneous-Metam
2606		2963	Igneous

The Livingstone Cove Formation is the middle unit of the Late Proterozoic Georgeville Group - an intra-arc basin deposit within the Avalon cratonic, magmatic arc terrane. The 610-625 Ma old zircons are inferred to have been derived from the magmatic arc, while the 1-1.2 Ga zircons probably came from its continental basement which is exposed in northwestern Cape Breton Island (previously dated at 1172+135/-73 Ma and 918+78/-179 Ma, U-Pb chord). The source of the older zircons is also inferred to be in the magmatic arc basement; however, a multistage sedimentary transport history cannot be ruled out. The near concordance of the 1520-1550 Ma, 1835 Ma and 1950-2000 Ma ages suggests that tectonothermal events took place at these times. The association of c. 600 Ma and 1 Ga is present in the southern Appalachians (1031 ± 94 Ma old Goochland Terrane surrounded by Late Proterozoic Carolina, Spring Hope, Roanoke Rapids and Charleston terranes), and in northwestern South America. These data suggest that the Avalon Compcsite

1 In: Abstracts from Terranes in the Circum-Atlantic Paleozoic Orogens; International Conference on Paleozoic Orogens in Central Europe, Gottington-Giessen, Germany, August - September 1990; International Geological Correlation Program 233

2 Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada M5S 2C6

terrane may have originated in South America rather than in northwest Africa as is commonly assumed.

The two turbidite samples were collected from the top and about 5 km below the top of the (?) Cambrian Goldenville Formation of the Meguma Group. The results show that the source of both sediments contained volcanic-plutonic components ca. 600 Ma and 2000 Ma old, whereas a third 3000 Ma component occurs exclusively in the upper sample and the youngest zircons and titanite are found in the lower sample. Lead-lead ages of bulk fractions at 2300 Ma and two nearly concordant single grains at 2040 Ma and 2140 Ma (upper sample), and 2157 Ma (bulk fraction) and 2060 Ma and 2080 Ma single grain fractions (lower sample) indicate that the ca. 2000 Ma component dominates the pink-purple, euhedral grain types. Detrital titanite samples give ages of 605 Ma (upper sample) and 552 Ma (lower sample) with the latter sample containing a minor ca. 1975 Ma component. Colourless zircons record this same age difference. The lower sample contained the youngest, concordant, single zircon grain (566 Ma) and a 580-605 Ma bulk fraction, even though two concordant single grains have ages of 632 and 643 Ma. Estimated bulk fraction ages for certain zircon grain types from the upper sample fall in the range of 605 to 675 Ma. These data suggest that while the youngest rocks in the source region were removed by erosion during the early stages of deposition of the Goldenville Formation, the oldest source rocks were not unroofed until later in the depositional history. The 566 $\pm$ 8 Ma age of the youngest concordant zircon from the stratigraphically lower sample provides a maximum age for its deposition. With the base of the Cambrian placed between 545 and 530 Ma, the Goldenville Formation may straddle the Precambrian - Cambrian boundary. Graptolites from the immediately overlying Halifax Formation are of Early Ordovician (Tremadocian) age. The lower sample contains spherical zircons that may have been derived from mafic granulite with an estimated age of 2000 to 2200 Ma. With this one possible exception, all of the zircons analyzed appear to be igneous in origin and all are relatively euhedral as if rocks with these ages outcrop in the source area. Anomalous discordance patterns imply that part of the 2960 Ma area may have been metamorphosed by the 2000 Ma event, and that parts of both the 2960 and 2000 Ma regions were probably metamorphosed during the 600 Ma event.

The complete lack of detritus in the Goldenville Formation with ages between 680 and 2040 Ma, whereas such detrites is present in the Livingstone Cove Formation, suggests that there were no links between them in Cambrian time or that the source of the Goldenville Formation was not in the Avalon composite terrane. The latter possibility is supported by the current directions in the Goldenville Formation that indicate a southern source region. These data do not eliminate the possibility that the Meguma terrane lay adjacent to the Avalon Composite terrane in Early Paleozoic times. The absence of 680-2040 Ma detritus in the Goldenville Formation virtually eliminates a northeastern North American or Baltic Shield provenance. However, available data are not sufficient to distinguish between a West African or Guyana Shield source.

Granitoid plutons cutting the Cambro-Ordovician Meguma Group yielded intrusive ages of 373 $\pm$ 2 Ma (U-Pb on concordant monazite and zircon). Single zircon grains in the plutons yield discordant data that project to between 2050 and 2320 Ma when plotted on a chord through 373 Ma. The similarity of these data and the older detrital grains in the Goldenville Formation suggests that these zircons in the plutons are xenocrysts derived from the Goldenville Formation, but derivation from the source region of the magma could be another possibility. The analysis of zircon cores isolated from grains with a large magmatic overgrowth provides an age for the source region. Data for nine cores from two granites define a line between 373 and 623 Ma. On the other hand, because three cores from one of the granites are coincident, it is possible that a slightly younger source may also be present. This magma is interpreted to have been produced after obduction of the Meguma Terrane that depressed the lithosphere, followed by a slow rise in the isotherms leading to melting of the lower crust. The ca. 623 Ma ages indicate that this was the age of the lower crust ca. 370 Ma ago. Previously published data indicate that the average T_{CHUR} and (T_{DM}) model ages for xenoliths in 370 Ma old lamprophyre dykes are: (1) 445-540 Ma and 1040-1107 Ma for metasedimentary xenoliths, respectively; and (2) <0-261 Ma and 536-1015 Ma for meta igneous xenoliths, respectively. These data may be correlated with the sequence in the Avalon Composite terrane consisting of Early Paleozoic rocks overlying a 550-640 Ma volcano-sedimentary package that is inferred to overlie a 1-1.2 Ga high grade suite. Such a correlation supports the structural model in which the Meguma terrane was thrust over the Avalon Composite terrane in the Late Paleozoic.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy
Report 91-1, p. 91

THE EAST KEMPTVILLE TOPAZ-MUSCOVITE LEUCOGRANITE, NOVA SCOTIA: I. GEOLOGICAL SETTING AND WHOLE-ROCK GEOCHEMISTRY[1]

D. J. Kontak

The East Kemptville leucogranite, a ca. 370 Ma topaz-muscovite leucogranite occurring at the southwest termination of the Late Devonian South Mountain Batholith of Nova Scotia, is petrologically significant because it represents the first documented occurrence of magmatic topaz in granitic rocks of the Meguma Zone and is also host to the only primary, producing tin deposit in North America (56 million tonnes at 0.165% Sn). Previous radiometric ages of ca. 300 Ma ($^{40}Ar/^{39}Ar$ muscovite) and ca. 337 Ma (Rb/Sr whole-rock) for the East Kemptville leucogranite are herein reinterpreted to reflect updating related to thermotectonic disturbances rather than the age of crystallization.

The leucogranite is medium grained, equigranular and characterized by the presence of magmatic topaz and muscovite; rare, small (<0.1 mm) biotite grains occur. The absence of fluid-saturation textures (e.g., miarolitic cavities, unidirectional solidification textures, pegmatites) indicate emplacement of the leucogranite as a H_2O - undersaturated melt. Although petrographic observations indicate subsolidus modification of primary magmatic mineralogy and textures, the leucogranite is considered to reflect a magmatic, rather than metasomatic phenomenon. Chemically the leucogranite is characterized by elevated concentrations of SiO_2, Al_2O_3 ($1.13 < A/CNK < 1.84$), total Fe, P_2O_5, Rb, Cs, Ga, Li, F, Sn, Nb, Cu, Zn, W, U, Ta and depleted levels of TiO_2, CaO, MgO, Ba, B, Th, V, Co, Sc, Hf, Zr, Ni, Mo, Sb and Y. Compared to evolved units (i.e., leucogranite) of the South Mountain Batholith, the leucogranite is enriched in Ta, Sr, Rb, F and Li, whereas REE abundances and chondrite-normalized patterns are markedly different. Geochemically the leucogranite compares favourably to other F-rich felsic suites, particularly topaz granites. The East Kemptville leucogranite is considered to represent the highly fractionated product of a strongly peralumious melt, itself derived via melting of a fluorine-rich biotite phase. The leucogranite may not represent a fractionate of the South Mountain Batholith (or Davis Lake Complex). The location of the East Kemptville leucogranite within a major northeast-trending shear zone may indicate that structure was involved in both generation and emplacement of the leucogranite.

1 In: Canadian Mineralogist, v. 28, 1990, p. 787-825

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 92

THE EAST KEMPTVILLE TOPAZ-MUSCOVITE LEUCOGRANITE, NOVA SCOTIA: II. MINERAL CHEMISTRY[1]

D. J. Kontak

Major and trace element chemistry of the mineral constituents of the East Kemptville leucogranite reflects chemical equilibration at both the magmatic (muscovite, bulk alkali feldspar, some biotite, topaz) and postmagmatic (albitic plagioclase, exsoved alkali feldspar, apatite in albite, most biotite, biotite alteration products) stages. Muscovite is characterized by elevated Fe (to 12 wt.% FeO) and F (to >4 wt.%) with low Fe^{3+}/Fe^{2+} ratios (0.137); absolute abundances of selected trace elements and ratios indicate compositions similar to white micas from pegmatites. The bulk composition ($Or_{82}Ab_{17}An_1$) and trace element chemistry of alkali feldspar are also more typical of pegmatites. Topaz chemistry [F/(F+OH) = 0.80 ± 0.05] is consistent with high formation temperatures, the inferred mineral assemblage and relatively dry nature of the melt. Biotite compositions vary considerably from freshest [Fe/(Fe+Mg) = >0.95, low Ti (<1.14 wt.% TiO_2), 2.7 wt.% F] to chemistries that deviate considerably from ideal trioctahedral chemistry due to postmagmatic alteration. The albitic (Ab_{99}) composition of plagioclase containing abundant apatite inclusions reflects a late-magmatic or early postmagmatic albitization of precursor Ca-bearing plagioclase.

The mineral chemistry indicates a highly reduced nature for the melt, similar to topaz rhyolites. Collectively, (1) the presence of muscovite, (2) feldspar thermometry and (3) covariation of K and Rb between alkali feldspar and muscovite indicate a T of 500-700°C, while primary muscovite suggests P was ≥ 1 kbar. Postmagmatic equilibration continued to ≤350°C based on (1) the presence of chloritic alteration of biotite and (2) two feldspar thermometry of exsolved phases in alkali feldspar. Postmagmatic alteration proceeded under low $f(O_2)$ as secondary biotite is characterized by elevated Fe/(Fe+Mg) ratios.

1 In: Canadian Mineralogist, v. 29, 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 93

$^{40}AR/^{39}AR$ CHRONOLOGICAL STUDY OF THE LISCOMB COMPLEX, MEGUMA TERRANE, SOUTHERN NOVA SCOTIA[1]

D. J. Kontak, A. K. Chatterjee, P. H. Reynolds[2] and K. Taylor[2]

The Liscomb Complex (LC) of southern Nova Scotia consists of high-grade metavolvanic and metasedimentary gneisses (age unknown), granitic intrusions and gabbroic intrusions which are collectively enveloped by Lower Paleozoic Meguma Group lithologies. Field relationships indicate that (1) gneisses of the LC truncate Acadian-age structures in the Meguma Group, (2) xenoliths of the gneisses occur within both the gabbroic and granitic intrusions, and (3) leucocratic dykes cut gabbroic rocks. Hence, the inferred chronology of emplacement is (1) diapiric emplacement of the gneisses, (2) gabbroic intrusion and (3) granite intrusion; all phases are post-Acadian in age (i.e., $\leq$ ca. 400 Ma). In order to establish an absolute time frame of events and study the thermal history of the region, $^{40}Ar/^{39}Ar$ analyses of mineral phases from all units were attempted and preliminary results obtained on 2 amphiboles (amph), 7 biotite (bt) and 5 muscovites (ms) are reported.

Granitic Intrusions: 5 concordant bt and ms age spectra indicate apparent ages of ca. 370 Ma; this includes a bt-ms pair from one granite sample.

Gabbroic Intrusions: 2 amph gave internally concordant age spectra with plateau ages of ca. 370 Ma, while 3 bt analyzed gave either older plateau ages (ca. 376 Ma) or internally discordant age spectra (integrated ages of 377 Ma to 385 Ma).

Gneisses: bt in gneiss immediately adjacent to granite gave a plateau age of ca. 375 Ma, while samples (2 bt, 1 ms) removed from the granite-gneiss contact gave plateau ages of ca. 375 Ma.

The $^{40}Ar/^{39}Ar$ data corroborate the field relationships and, furthermore, indicate that the gneisses may have been emplaced and cooled below the blocking temperatures of the mica phases (300-350°C) at 375 Ma, some 5 Ma prior to the intrusion of felsic and mafic rocks. The concordant amph, bt and ms ages for the intrusions indicate rapid post-crystallization cooling. The anomalously old ages for bt from the gabbroic samples may reflect an excess Ar contaminant.

---

1 In: Atlantic Geology, v. 26, p. 176-177
2 Department of Geology, Dalhousie University, Halifax, N. S. B3H 3J5

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 94

GEOCHRONOLOGICAL EVIDENCE FOR MULTIPLE TECTONO-THERMAL OVERPRINTING EVENTS IN THE EAST KEMPTVILLE MUSCOVITE-TOPAZ LEUCOGRANITE, YARMOUTH COUNTY, NOVA SCOTIA, CANADA[1]

D. J. Kontak and R. F. Cormier[2]

The East Kemptville muscovite-topaz leucogranite, located in Yarmouth County, Nova Scotia, Canada, is host rock to the only producing, primary tin deposit in North America (56 Mt, 0.165% Sn). Previous geochronological studies include (i) Rb-Sr whole-rock analyses of the quartz-topaz greisens, which indicated a date of 337 ± 5 Ma and (ii) $^{40}Ar/^{39}Ar$ analyses of greisen muscovite, which indicated apparent plateau dates of ca. 300 Ma. However, the pervasive development of deformational fabrics at East Kemptville suggests that both the Rb-Sr whole-rock and $^{40}Ar/^{39}Ar$ muscovite ages are at best minimum estimates for the inferred time of mineralization. In the present study, Rb-Sr whole-rock and mineral (muscovite, plagioclase, K-feldspar) analyses, and $^{40}Ar/^{39}Ar$ incremental-step heating of a muscovite separate indicate the following: (i) diffusion of Sr on the whole-rock scale terminated at 344 ± 5 Ma (11 point isochron date), coincident with closure of muscovite to intracrystalline diffusion of Ar (apparent plateau date of 338 ± 2 Ma); (ii) internal re-equilibration of Sr among muscovite, feldspar and whole rock varied considerably such that Rb-Sr whole-rock - muscovite pairs give dates of 361-311 Ma (mean = 330 Ma, n = 7), whereas whole-rock - plagioclase - K-feldspar give dates of 276-240 Ma (mean = 254 Ma, n = 7). This younger thermal event is reflected in apparent dates of 269-286 Ma for the low temperature steps of the $^{40}Ar/^{39}Ar$ muscovite age spectrum.

Collectively the data indicate that the East Kemptville area either cooled slowly over a protracted period of time (ca. 100 Ma) or experienced episodic tectono-thermal activity at ca. 344, 330 and 254 Ma. Examination of previously published geochronological data for the southern Meguma Terrane indicates that these aforementioned ages broadly coincide with earlier documented magmatic or tectono-thermal events (e.g., intrusion of Wedgeport Pluton at 315 Ma). Inferences by some workers of mid-Carboniferous magmatism in the Meguma Terrane are, however, not supported by the present study.

1 In: Canadian Journal of Earth Sciences, v. 28, 1991, p. 209-224
2 Department of Geology, St. Francis Xavier University, Antigonish, N. S., Canada B2G 1C0

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 95

RB/SR AND $^{40}AR/^{39}AR$ GEOCHRONOLOGICAL STUDIES OF THE TIN-BEARING EAST KEMPTVILLE LEUCOGRANITE, S. W. MEGUMA TERRANE, NOVA SCOTIA: EVIDENCE FOR MULTIPLE EPISODES OF TECTONO-THERMAL PERTURBATIONS[1]

D. J. Kontak, R. F. Cormier[2] and P. H. Reynolds[3]

The East Kemptville tin deposit is hosted by a topaz-muscovite leucogranite which intrudes Cambro-Ordovician metasedimentary rocks of the Goldenville Formation. The presence of penetrative deformation within the leucogranite (S surfaces, C-S fabrics, mylonites) suggests that post-crystallization modification of both whole-rock Rb/Sr (337 Ma) and $^{40}Ar/^{39}Ar$ (295 Ma) isotopic systems occurred, thus neither age reflects the time of intrusion or tin mineralization as suggested by the respective authors. We report here results of a geochronological study designed to define the age of crystallization of the leucogranite and timing of the overprinting tectonic events.

Rb-Sr analyses of the least deformed and chemically pristine samples of leucogranite gave the following results: (1) 11 whole-rock (WR) samples define an age of 353 $\pm$ 6 Ma (MSWD = 1.78 F-value = 2.72), Sr(i) = 0.7269; (2) 9 WR samples minus their muscovite (WRMMS) define an age of 368 $\pm$ 13 Ma (MSWD = 9.66, F-value = 2.83), Sr(i) = 0.7208; (3) 7 muscovite (MS) separates define an age of 334 $\pm$ 2 Ma (MSWD = 2.41; F-value = 3.03), Sr(i) = 0.7462; (4) WR-WRMMS-MS ages for 7 samples define ages from 372 Ma to 324 Ma with a spread of Sr(i); and (5) WRMMS - K-feldspar - plagioclase (quartz) ages for 7 samples define ages from 270 Ma to 249 Ma. A $^{40}Ar/^{39}Ar$ age spectrum for the most pristine muscovite available is discordant with the low temperature gas defining an apparent age of ca. 338 Ma. In contrast, a plateau age of ca. 338 Ma is defined by the high temperature gas fraction which includes 66% of the gas released.

The isotopic data are interpreted to indicate initial closure of the Rb/Sr whole rock system at ca. 353 Ma with subsequent resetting of the muscovite and feldspar mineral systems at ca. 334 Ma and ca. 260 Ma. The 334 Ma event completely outgassed the muscovite analyzed in this study, while an event of post 300 Ma age caused partial outgassing. The heterogeneous nature of the tectono-thermal events is reflected by the variable WR-WRMMS-MS and WRMMS-KF-QP Rb/Sr isochrons and variable $^{40}Ar/^{39}Ar$ muscovite age spectra thus far obtained at East Kemptville.

---

1 In: Atlantic Geology, v. 26, p. 177

2 Department of Geology, St. Francis Xavier University, Antigonish, Nova Scotia B2G 1C0

3 Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 96

A MINERALOGICAL AND FLUID INCLUSION STUDY OF THE WEST GORE SB-AU DEPOSIT, CENTRAL MEGUMA TERRANE, NOVA SCOTIA: A POSSIBLE HIGH-LEVEL ANALOGUE FOR MESOTHERMAL MEGUMA GROUP LODE-GOLD DEPOSITS[1]

D. J. Kontak and P. K. Smith

Mineralization at the West Gore Sb-Au deposit (7158 oz. Au produced), hosted by NE-trending slates of the Halifax Formation, occurs within three, subparallel and subvertical, NW-trending fault structures. Vein fill is dominated by unstrained, bimodal quartz (coarse prismatic and fine-grained equant) and paragenetically later carbonate+chlorite and associated ore minerals occupying vugs or orthogonal fractures. The ore assemblage consists of early stibnite, locally replacing po, with associated po ± py ± arspy ± Fe-rich sph ± cpy ± native antimony. Stibnite occurs either as coarse blebs or delicate, acicular to reticulate grains intergrown with quartz and/or carbonate. Stibnite is replaced by a complex, concentrically zoned intergrowth of native Au (<1 wt.% Ag) and colloform-textured Au-Cu alloy; this assemblage is frequently accompanied by zones of carbonate±chlorite enrichment. The latest stage of mineralization consists of Fe- and Mn oxides and secondary Sb minerals [kermesite (Sb_2S_2O) and valentinite (Sb_2O_3)].

Fluid inclusions (quartz only; 5-15 μ size) occur as (1) isolated groups or (2) planar arrays along healed microfractures. The cores of prismatic quartz grains are generally inundated with inclusions whereas the margins are inclusion-free; hence, a probable primary or pseudo-secondary origin for the inclusions. Inclusion types are: (i) V-rich (H_2O), (ii) L-rich (H_2O), and (iii) H_2O-CO_2 (X_{CO2}=0.1). While type (iii) are rare, (i) and (ii) are abundant and their mutual coexistance suggests fluid unmixing. Thermometric data (°C) are summarized as follows: (1) $T_m(CO_2)$=-58.7±1.0 (n=8); (2) T_m(ice)=-4.0±1.0 (n=50; ca. 5-8 wt.% equiv. NaCl); (3) $T_h(CO_2)$=25.4±0.8 (n=4; to L) and 13.3 (N=1; to V); and (4)$T_h(H_2O)$=ca. 200-400 (n=177; to L) and 370 (n=5; to V). In addition, (1) clathrate formation indicates ca. 1 mol% dissolved CO_2 in type (ii) inclusions, (2) decrepitation is common between 300-400°C, (3) there is no correlation between salinity and $T_h(H_2O)$ and (4) ambient pressure of formation is estimated at 0.6 kbar (ca. 1700 m lithostatic cover).

1 Presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 97

GEOLOGICAL AND $^{40}AR/^{39}AR$ GEOCHRONOLOGICAL CONSTRAINTS ON THE TIMING OF QUARTZ VEIN FORMATION IN MEGUMA GROUP LODE-GOLD DEPOSITS, NOVA SCOTIA[1]

D. J. Kontak, P. K. Smith, P. Reynolds[2] and K. Taylor[2]

The results of geological and $^{40}Ar/^{39}Ar$ geochronological investigations of several gold districts hosted by the Meguma Group are presented. Observations at both the macro- (deposit to ore zone) and micro- (hand sample to thin section) scale indicate that quartz vein formation followed major Acadian folding and metamorphism (ca. 400 $\pm$ 10 Ma) and was broadly coincident with mafic-felsic magmatism at ca. 370 Ma. $^{40}Ar/^{39}Ar$ analyses of vein-fill mica and amphibole from the Beaver Dam, Moose River, Fifteen Mile Stream, Upper Seal Harbour and Caribou deposits indicate ages of ca. 380 Ma to ca. 362 Ma. The age data are interpreted to reflect discrete hydrothermal events with rapid cooling following crystallization of vein constituents. The age data do not reflect either variable amounts of resetting by later granitic intrusions or diachronous cooling. Genetic models that interpret the generation of the auriferous quartz veins as either before or during major Acadian folding are considered to be inconsistent with the present results. Instead, a model is favored that interprets quartz vein formation in the context of continued transpression of the Meguma Terrane following regional folding and metamorphism.

1 In: Atlantic Geology, v. 26, 1990, p. 201-227
2 Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5, Canada

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 98

ABSOLUTE DATING OF MEGUMA GOLD MINERALIZATION IN THE EASTERN MEGUMA TERRANE USING $^{40}AR/^{39}AR$ TECHNIQUE: CHRONOLOGICAL EVIDENCE FOR CONVERGENT METALLOTECTONIC PROCESSES IN THE MEGUMA TERRANE AT CA. 370 MA[1]

D. J. Kontak, P. K. Smith, P. H. Reynolds[2] and K. Taylor[2]

Gold mineralization in the Meguma Terrane is hosted by Lower Paleozoic metaturbidites of the Meguma Group. The deposits are preferentially localized in steep, frequently overturned limbs of antiformal structures and more rarely hinge zones; other structures (e.g. kink zones) may also be important. Gold is confined to white, crystalline quartz which is generally late in the paragenesis and is associated with Cu, Pb, Zn sulphides and Bi-Ag tellurides. Fluid inclusion and isotopic (C, O) data indicate remarkable uniformity among gold districts. Petrofabric studies of vein materials indicate vein formation post-dated regional metamorphism and deformation as a shear cleavage axial planar to the folded quartz veins overprints the regional (i.e. Acadian age) fabrics.

The age of vein formation at 5 districts (Beaver Dam, Caribou, Moose River, Upper Seal Harbour, Fifteen Mile Stream) has been obtained via $^{40}Ar/^{39}Ar$ analyses of vein-hosted biotite, muscovite and amphibole. The data are generally similar with plateau ages of ca. 370 $\pm$ 5 Ma defined for most samples. There is no evidence for partial resetting of any sample and in all cases ages close to the time of mineral, and hence vein, formation are indicated. Consideration of resetting of mineral ages via granitic intrusions is unlikely given the variable distances of deposits from such bodies, the lack of evidence for convective cooling of Meguma Terrane granites, and the large range in blocking temperatures for the dated minerals (i.e. $\geq$ 500°C to $\leq$ 300°C).

The formation of Meguma gold deposits at ca. 370 Ma is considered to be sensibly coincident with intrusion of large volumes of granitic ($\pm$ mafic) magma and shear zone development throughout the Meguma Terrane. The convergence of these processes, which together created structural anisotropies for thermally generated metamorphic fluids, is considered to be an important part of gold metallogeny in the Meguma Terrane.

---

1 In: Atlantic Geology, v. 26, p. 177-178

2 Department of Geology, Dalhousie University, Halifax, Nova Scotia B3H 3J5

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 99-100

SPANS GIS: MODELLING OUR CHEMICAL ENVIRONMENT[1]

P. J. Rogers

Increasing awareness of the environment as a global issue has important implications for mineral exploration and extraction. The earth consists of a multitude of ecologically distinct zones defined by the complex interactions of climate, geology and biosphere. The surface of the earth can also be considered in terms of various landscape types, either abiogenic (deserts) or biogenic (wooded, steppe or tundra). Within these landscape types operate the processes of physical and chemical weathering, including the movement of chemical elements from the geological substrate into surficial materials.

Since the early 1950s exploration geochemical surveys have been carried out on a variety of surficial materials in Nova Scotia. To date most of this effort has been directed exclusively at resource potential applications with the intention of stimulating development in the mineral sector of the economy. During this exploration phase an extensive geochemical database has been collected. A traditional mineral producer, Nova Scotia has a high population density sharing a relatively small area. This demographic reality exacerbates a land use issue often represented as a conflict between the desire for a clean environment versus the need to generate wealth from the abundant mineral resources of the province. The impact of mineral development on the landscape and quality of life is an important environmental issue in North America and especially Maritime Canada.

The concept of geochemical background, developed for mineral exploration, enables chemical flow paths and barriers to be identified in the environment or landscape. Recent computer technology has brought forth a new generation of powerful personal computers that can easily and cheaply operate sophisticated geographic information system (GIS) programs in the office or home. These GIS programs allow the integration and spatial modelling of numerous geoscientific datasets, including exploration and environmental data. Application of GIS technology to data collected through decades of mining activity make it possible to construct a geochemical map of the world to establish global geochemical backgrounds.

Using SPANS GIS, background levels for various lithological units can be estimated based on the areal extent and level of stream sediment response in the Cobequid Highlands of Nova Scotia. Use of SPANS GIS also allows the integration and modelling of satellite imagery, geophysical data and other digital land information.

The quantification and estimation of these chemical background levels are an important part of environmental impact studies. Some yardstick or baseline to establish natural elemental abundances for a particular landscape is needed to comparatively judge the impact of some new environmental stress.

Chemical changes to the landscape are themselves natural phenomena that can be documented by long cores of lake sediments. Long-term changes to environmental landscapes have been detected in North America using lake sediment long cores, which may collect a lake's complete depositional record since lakes were established after the last Ice Age. In Ontario and Nova Scotia distinctive pollen horizons are noted which enable biostratigraphic correlations to be made between different lake sediment basins. Long-term changes in such elements as zinc, copper and lead are noted as the lake basins mature with time. The lake

1 In: Geomatics Association of Nova Scotia Newsletter, v. 1, no. 1, p. 6

cores also outline chemical changes due to acidification, either natural or man made, construction and industrial activity within the catchment basin.

The environmental bottom line must therefore include a baseline that represents the chemical and physical nature of the landscape. The application of modern exploration and GIS technology enables this bottom line to be established at the local, regional and global scale.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 101

MINERAL EXPLORATION USING CATCHMENT BASIN ANALYSIS TO INTEGRATE REGIONAL STREAM SEDIMENT GEOCHEMICAL AND GEOLOGICAL INFORMATION IN THE COBEQUID HIGHLANDS, NOVA SCOTIA[1]

P. J. Rogers, G. F. Bonham-Carter[2] and D. J. Ellwood[2]

Stream sediment and stream water geochemical data from the Cobequid Highlands are displayed in a series of maps, using catchment basins as the zone of influence for sample locations. The maps include: raw element plots, using a percentile classification scale; anomaly maps for each element, after background removal; and a geochemical province multi-element map based on a 3-colour plot of the first three principal components. Geochemical background is determined using a model that predicts element levels in terms of mixing of surface materials derived from the bedrock units present in each catchment basin. Catchment basins used as the area of influence allow integration of geochemical and geological maps with other geoscientific data such as geophysics and remote sensing.

The variability of many elements found in the stream sediment samples can be largely explained by the mixing model and knowledge of the underlying bedrock geology of stream catchment basins. Up to 40% of the variability of Zn and Pb and over 30% for Cu, F (in water), Fe, Ag, As and Ni can be assigned to mapped geology. Secondary scavenging in the surficial environment of Zn, Pb, Cu, As, Ni and Co is shown by high correlations with Fe and Mn. Residual maps, where the variability associated with catchment geology and secondary scavenging has been removed, delimit more subtle anomalies indicating areas of exploration potential.

The Cobequid Highlands has been explored on an intermittent basis since the early 1960s for Cu, Pb, Zn, U and, to a limited extent, Au. The result of the catchment basin modelling of the stream sediment data indicates a close correlation between known mineralization and elevated values in stream catchments.

1 In: Statistical Applications in the Earth Sciences, ed. F. P. Agterberg and G. F. Bonham-Carter; Geological Survey of Canada, Paper 89-9, 1989

2 Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 102

METALLOGENIC DOMAINS AND THEIR REFLECTION IN REGIONAL LAKE SEDIMENT SURVEYS FROM THE MEGUMA ZONE, SOUTHERN NOVA SCOTIA[1]

P. J. Rogers, A. K. Chatterjee and J. W. Aucott[2]

Approximately 3000 samples from a regional centre-lake bottom sediment survey of southern Nova Scotia were re-analyzed for sixteen elements of metallogenic significance. Analytical results for Cu, Pb, Zn, Ag, Li, F, Nb, Sn, Ti, Zr, Rb, Th, Sb, As, W and Au confirm that most known mineral deposits and metallogenic domains in the Meguma Zone have detectable geochemical signatures in lake sediments. Lake sediment exploration is most effective for mapping when a catchment basin model is employed. In southern Nova Scotia, lake sediment surveys are especially useful when prospecting and selecting areas of potential lithophile mineralization. Mineralogical expressions of Sn, W, Th and Zr in lake sediment are reflected by the presence of discrete grains of cassiterite, scheelite or wolframite, monazite and zircon. Free gold has also been identified in lake sediment, and may be the cause of some identified Au anomalies. Lake catchment basins contain mixtures of hydromorphically and mechanically dispersed components. After relatively short transport distances from a bedrock or till source heavy minerals can be trapped in lake catchment basins. Meguma Zone lake sediment anomalies may be grouped into those dominated by these hydromorphic and mechanical-weathering processes.

Geochemical mapping using lake sediments is undertaken through the application of simple data reduction procedures using single- and multielement methods. Geochemical maps for individual elements are produced as computer-contoured colour plots at a fixed percentile scale. Maps for Sn, W, Au and Ag outline known mineral occurrences as distinct anomalies for the East Kemptville Sn-Zn-Cu±W, Millet Brook U-Cu-Ag and numerous Au vein deposits within defined bedrock metallogenic domains. Geochemical mapping of Au and Ag anomalies also indicates large-scale structures such as northwesterly-trending shear zones. Large shear zones are outlined by Au anomalies, and W highs define areas of new potential in exo-contact zones of the South Mountain Batholith. Gold potential for granitoid rocks is indicated by numerous Au anomalies. Associations of Cu-Pb-Zn-Ag, F-Li-Nb-Rb+Sn, Zr-Ti-Th and Sb-As-Au-W are plotted with multi-element score maps. Boundaries of the score maps closely follow the bedrock metallogenic domains and outline areas of potential economic mineralization. Regional geochemical mapping can be accomplished successfully, accurately and at reasonable cost using lake sediments. Modern analytical packages offer high-precision techniques for lake sediment analysis. Compared to regional till surveys in this area, lake sediment surveys cost less and have spatial attributes that produce data most suited to geochemical mapping projects.

1 In: Journal of Geochemical Exploration, Special Issue on International Geochemical Mapping, v. 39, p. 153-174
2 Datamine International, 1-2 Langham Place, London WIW 7DD, UK

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 103-104

BASELINE GEOCHEMICAL MAPPING USING LAKE SEDIMENTS[1]

P. J. Rogers, J. A. C. Fortescue[2] and J. G. Ogden[3]

Lake drainage systems cover large parts of the Canadian landmass. For this reason lake sediments have been used extensively during the past 15 years as a medium for mineral exploration or resource appraisal geochemical mapping (Hornbrook, 1989). Grab samples of lake sediment provide large multi-element geochemical databases well suited to mineral exploration purposes (Rogers and Chatterjee, in press). These grab samples may lack stratigraphic detail, however, and when mineral resource appraisal and geochemical baseline information is desired from lakes, sediment cores are required. Lake sediment is perhaps unique as a mapping tool as it defines both spatial and temporal aspects of the catchment's landscape evolution. Indeed, lake sediment has been likened to a mass storage device for historical geochemical data derived from the catchment (Ogden *et al.*, 1988). Geochemical data from lake sediment cores may be used (1) for geochemical mapping, (2) in pollution studies and (3) in investigations of global climatic change. If lake sediment cores are used as a medium for geochemical mapping, such mapping may relate to anthropogenic input of elements during the past few hundred years and/or to material laid down prior to the advent of modern man in lake catchments of interest.

These sediment cores are of two kinds: 'short cores' (30-40 cm long), which usually include sediment laid down during the past 200 years, and 'long cores', which penetrate the entire organic layer at the bottom of a lake and are usually 3-5 m long. Short cores are used in acid rain studies to trace the pH history of lakes during the past 200 years using geochemical and diatom-inferred pH methodologies (Fortescue, 1984, 1985). Lake sediment long cores include material laid down since the last Ice Age and can be used to describe the geochemical, palynological and diatom history of lake catchment areas.

Data from Ontario and Nova Scotia demonstrate that spatial correlations and temporal markers from lake to lake can be established by these methods. For example, a ragweed (Ambrosia Spp.) pollen layer in Ontario and a Plantago Spp. pollen layer in Nova Scotia have both been used extensively to date the chemical stratigraphy of lake sediment cores collected from these areas.

Our lake sediment core case histories also describe at least four types of Canadian acid lakes. Some of these lakes are naturally acid and others have become acid due to acid rain, pollution and/or environmental degradation. The geochemistry of post-Ambrosia environmental disturbances has been noted from lakes near smelters in Ontario and from the post-Plantago layer at Chocolate Lake, Nova Scotia. Dramatic increases in baseline metal values (e.g. by Pb due to automobiles, Cu due to modern plumbing, V due to home heating oil, etc.) are observed in most lake sediment cores. Cores from some Nova Scotia lakes include a geochemically distinct 'backhoe' horizon caused by accelerated bedrock weathering due to excavation and construction activities in catchment areas about 40 years ago (Ogden *et al.*, 1988). Certain elements can also be used as time and spatial or ballistic markers. For example Ni, Cu, U, Br, As, Sb and Co have been found useful in Ontario and Al and Zn at Soldier Lake in Nova Scotia (Fortescue, 1986; Ogden and Rogers, 1988).

---

1 In: Extended Abstracts, Methods of Geochemical Prospecting, eds. J. Janatka, T. Hlavatâ, I. Barnet and E. Jelinek; Geological Survey, Prague, CSSR, p. 65-66

2 Ontario Geological Survey, Ministry of Northern Development and Mines, 77 Grenville Street, Toronto, Ontario, Canada M7A 1W4

3 Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1

All post-glacial lakes in central and eastern Canada show an increased organic content with time from ca. 10,500 to 9,000 radiocarbon years before present (RYBP). This increase is a consequence of decreased soil erosion and increasing vegetation as post-glacial warming permitted a re-establishment of closed boreal forests. In Nova Scotia, lake sediment cores record a distinct climatic change to a warm, dry maximum at ca. 3500-5500 RYBP, the xenothermal interval. Reduced precipitation and runoff during this time lowered flushing rates and increased organic sedimentation. The possible effects of future global warming can be inferred from such data on previous periods of global warming recorded in long cores.

Lake sediment short and long cores provide a means to establish both a spatial and temporal baseline datum for geochemical mapping. Short cores may provide detailed evidence for increased acidification and/or input of elements due to man's activities during the past several hundred years. Long lake sediment cores, taken from all ecological zones in the world, would provide unique spatial and temporal information pertinent to the preparation of a world geochemical map.

REFERENCES

Fortescue, J. A. C. 1984: Interdisciplinary research for an environmental component (acid rain) in regional geochemical surveys (Wawa area), Algoma District; Ontario Geological Survey, Map 80 713, Geochemical Series, compiled 1983.

Fortescue, J. A. C. 1985: Preliminary studies of lake sediment geochemistry in an area northeast of Sudbury, Sudbury and Temiskaming Districts; Ontario Geological Survey, Map 80 756, compiled 1985.

Fortescue, J. A. C. 1986: Geochemical stratigraphy of organic lake sediments from selected lakes north and east of Lake Superior; Ontario Geological Survey, Map 80 757, Geochemical Series, compiled 1985.

Hornbrook, E. N. W. 1989: Paper 32: Lake sediment geochemistry: Canadian applications in the eighties; *in* Proceedings of Exploration '87: Third Decennial International Conference on Geophysical and Geochemical Exploration for Minerals and Groundwater, edited by G. D. Garland; Ontario Geological Survey, Special Volume 3, p. 405-416.

Ogden, J. G. and Rogers, P. J. 1988: Biological and geochemical sedimentation along a pH gradient in Soldier Lake, Halifax County, Nova Scotia; *in* International Groundwater Symposium on Hydrogeology of Cold and Temperate Climates and Hydrogeology of Mineralized Zones; Proceedings, edited by C. L. Lin; Halifax, Nova Scotia, Canada, May 1-5, 1988, p. 201-210.

Ogden, J. G., Carrigan, L. M. and March, K. L. 1988: The geochemical care and feeding of mud; *in* Prospecting in Areas of Glaciated Terrain 1988, eds. D. R. MacDonald and K. A. Mills; Canadian Institute of Mining and Metallurgy, p. 357-382.

Rogers, P. J. and Chatterjee, A. K. in press: Metallogenic domains and their reflection in regional lake sediment surveys from the Meguma Zone, southern Nova Scotia, Canada; Journal of Geochemical Exploration.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 105-107

GEOCHEMICAL BACKGROUND: IMPLICATIONS FOR ENVIRONMENTAL GEOCHEMISTRY IN NOVA SCOTIA, CANADA[1]

P. J. Rogers and J. G. Ogden III[2]

Since the early 1950s exploration geochemical surveys have been carried out on a variety of surficial materials in Nova Scotia. To date most of this effort has been directed exclusively at resource potential applications with the intention of stimulating development in the mineral sector of the economy. During this exploration phase an extensive geochemical database has been collected. A traditional mineral producer, Nova Scotia has a high population density sharing a relatively small area. This demographic reality exacerbates a land use issue often represented as a conflict between the desire for a clean environment versus the need to generate wealth from the abundant mineral resources of the province. The impact of mineral development on the landscape and quality of life is an important environmental issue in North America and especially Maritime Canada.

Most geochemical exploration activity has concentrated on stream or lake drainage systems by sampling sediments and(or) surface waters. Lake and stream catchment basins are important repositories of geochemical information concerning the composition and characteristics of their drainage areas. Modern drainage systems can be considered as mass storage devices (Ogden *et al.*, 1988) which contain the 'geochemical genetic code' for each catchment. The extension of the catchment basin concept to exploration geochemistry (Bonham-Carter *et al.*, 1987) forms a bridge to environmental geochemistry. This paper will consider studies of a number of catchment basins in Nova Scotia.

One of the principal aims of exploration geochemistry is the estimation of geochemical background to define threshold levels and indicate anomalies. Recognition of 'natural' background levels in surface materials of various elements is needed to define baseline element levels and principal controls and to monitor changes in the ecosystem. Widely different element levels can be found in stream and lake systems. It is possible to define various natural and imposed geochemical controls present in stream and lake drainage systems. Principal geochemical factors governing background levels include catchment lithology, chemical mobility, and dispersion and dilution of metals during transport. pH is one of the most active geochemical factors and also the one most readily affected by imposed external loading such as from acidified rainfall. To estimate the pH effect on heavy metal mobilities, background levels and vector properties of these metals in natural systems must be elucidated.

Catchment basin analysis (CBA) has been used to characterize background for 1500 stream sediment and stream water samples from the Cobequid Highlands. Background is modelled for element concentrations in stream sediment as a function of the areal proportion of map units occuring within each catchment basin. Step-wise regression uses areal proportions of mapped units as independent variables to model geochemical background for Cu, Pb, Zn, Ag, Fe, Mn, Ni, Co, As, Hg, U and Mo in sediment and U, F and pH in water for each of 65 mapped lithologic units. Calculated background levels for each map unit are given as weighted means for each element. The model thereby determines a measure of the association between the geology and surficial geochemistry. Volcanic and granitic units of the central upland core have much higher

---

1 In: Extended Abstracts, Methods of Geochemical Prospecting, eds. J. Janatka, T. Hlavatá, I. Barnet and E. Jelinek; Geological Survey, Prague, CSSR, p. 27-28

2 Department of Biology, Dalhousie University, Halifax, Nova Scotia, B3H 4J1

background levels for most elements when compared to other units. After subtraction of background the residual variance of catchment basins reveals areas of anomalies, which as elevated concentrations could be seen as potential hazards in terms of heavy metal content. The CBA model also distinguishes variance due to scavenging by Fe and Mn, and pH effects on the mobility of elements such as U, Mo and As. Catchment basin plots for these elements clearly outline the pH response in terms of the underlying geology.

We call attention to, and illustrate, two important properties of limnic systems:

(a) Catchments with definable sub-watersheds can show distinctive biostratigraphic and geochemical signatures throughout the lake basin. We describe Soldier Lake, Halifax County, Nova Scotia (Ogden and Rogers, 1988) which has a hydrogen ion [H^+] gradient from distinct sub-watershed units ranging from 0.7 $\mu eq\ L^{-1}$ (pH 6.2) to 102.3 $\mu eq\ L^{-1}$ (pH 2.99). Mass balance studies (Ogden and Machell, 1985) indicate retention (presumably by deposition) of 33% of Al, 63% of organic C, and 85% of Fe entering the lake. Outlet pH values of 4.6 (25.1 $\mu eq\ L^{-1}$) imply neutralization of 38% of the [H^+] entering the lake. We show the presence of distinct geochemical and biostratigraphic (diatom) domains related to water chemistry, independent of regional (allocthonous) pollen deposition.
(b) Sediment cores from three connected lake basins in the St. Margaret's Bay area, Halifax County, Nova Scotia, which have shown substantial acidification, with pH values from 6.0 to 6.3 in 1979 and from 4.8 to 5.6 in 1987, reveal four goechemically (and biostratigraphically) distinct horizons or zones:
(1) Initial (ca. 12,500 RYBP (Radiocarbon Years Before Present)) high energy meltwater deposition of coarse (sand and gravel) sediment including a large proportion of extra-catchment materials, with little or no organic matter.
(2) A silt to clay transition horizon (ca. 11,500 RYBP) with very little organic carbon and very low hydraulic permeability (Ogden, 1986), which effectively seals an initial catchment geochemical signature unaffected by biological modification.
(3) A mid-postgalcial period of warm/dry conditions (3500-5500 RYBP) of reduced hydraulic throughput, increased organic production, and longer water residence times which provided increased opportunity for organic/inorganic geochemical interaction.
(4) A post-colonization period of increasing anthropogenic influence, land disturbance, and changing atmospheric geochemistry.

In the St. Margaret's Bay area, development and construction activities have been primarily limited to the Five Island Lake catchment area, and are mostly residential and seasonal cottage developments. A number of new residential developments are currently under way in this watershed and may be expected to change both runoff and water quality as development pressures continue to affect many of the present hydrogeochemical parameters. With increasing acidification we infer the development of geochemical deposition domains in these lakes in future, similar to those described for Soldier Lake.

REFERENCES

Bonham-Carter, G. F., Rogers, P. J. and Ellwood, D. J. 1987: Catchment basin analysis applied to surficial geochemical data, Cobequid Highlands, Nova Scotia; Journal of Geochemical Exploration, v. 29, p. 259-278.

Odgen, J. G., III 1986: The concept of the perilimnion; Proceedings of the Nova Scotian Institute of Science, v. 36, p. 137-144.

Ogden, J. G., III, Carrigan, L. M. and March, K. L. 1988: The geochemical care and feeding of mud; *in* Prospecting in Areas of Glaciated Terrain 1988, eds. D. R. MacDonald and K. A. Mills; Canadian Institute of Mining and Metallurgy, p. 293-303.

Ogden, J. G., III and Machell, J. 1985: Ionic and mass balances in a dilute acidified brown water lake; Proceedings of the Nova Scotian Institute of Science, v. 35, p. 75-90.

Ogden, J. G., III and Rogers, P. J. 1988: Biological and geochemical sedimentation along a pH gradient in Soldier Lake, Halifax County, Nova Scotia; *in* Hydrogeology of Cold and Temperate Climates and Hydrogeology of Mineralized Zones, ed. C. L. Lin; International Association of Hydrogeologists, p. 201-210.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 108-109

GEOCHEMICAL BACKGROUND: IMPLICATIONS FOR THE ENVIRONMENT[1]

P. J. Rogers, J. G. Ogden III[2] and J. A. C. Fortescue[3]

Increasing awareness of the environment as a global issue has important implications for mineral exploration and extraction. The Earth consists of a multitude of ecologically distinct zones defined by the complex interactions of climate, geology and biosphere. The surface of the earth can also be considered in terms of various landscape types, either abiogenic (deserts) or biogenic (wooded, steppe or tundra). Within these landscape types operate the processes of physical and chemical weathering, including the movement of chemical elements from the geological substrate into surficial materials.

Exploration geochemistry has been identifying and quantifying these chemical movements since the late 1940s in both North America and the Soviet Union. The concept of geochemical background is the foundation for this methodology as most mineral deposits have some sort of geochemically anomalous response, either positive or negative in amplitude. The mining industry has long been exploring and charting these chemical flow paths and barriers in the global landscape.

Recent computer technology has brought forth a new generation of powerful personal computers that can easily and cheaply operate sophisticated geographic information system (GIS) programs. This allows the integration and spatial modelling of numerous geoscientific datasets, including exploration and environmental information, so that it is now possible to estimate the chemical nature of the world's landscape in terms of geoscience data.

Quantification and estimation of these background levels are important functions when an environmental impact study is to be commissioned. Some yardstick or baseline to establish natural elemental abundances for a particular landscape is needed to judge the impact of some new environmental stress. Indeed, most mineral deposits have a chemical and physical response in the landscape, which is normally how they are found using geochemical or geophysical methods. A mineral deposit can therefore be considered to have an environmental impact in its own right. Thus the chemically natural baseline in the area of a mineral deposit will be much higher (or lower) than in other surrounding parts of the landscape. Mining can actually improve this environmental impact by removing an oxidizing orebody that is supplying heavy metal toxins into the landscape.

In Canada lake drainage systems cover large parts of the landmass and for this reason lake sediments have been used extensively during the past 15 years as a medium for mineral exploration or resource appraisal geochemical mapping. Grab samples of lake sediment provide large multielement geochemical databases well suited to mineral exploration purposes. These grab samples may lack stratigraphic detail, however, and when mineral resource appraisal and geochemical baseline information is desired from lakes, sediment cores are required. Lake sediment is perhaps unique as a mapping tool as it defines both spatial and temporal aspects of the catchment's landscape evolution. Indeed, lake sediment has been likened to a mass storage device for historical geochemical data derived from the catchment. Geochemical data from

---

1 In: Supplement to Mining Jounral, London, v. 315, no. 8085
2 Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada B3H 4J1
3 Ontario Geological Survey, Ministry of Northern Development and Mines, 77 Grenville Street, Toronto, Ontario, Canada M7A 1W4

lake sediment cores may be used for geochemical mapping, pollution studies and in investigations of global climatic change. If lake sediment cores are used as a medium for geochemical mapping such mapping may relate to anthropogenic input of elements during the past few hundred years and/or to material laid down prior to the advent of modern man in lake catchments of interest.

These sediment cores are of two kinds: 'short cores' (30-40 cm long), which usually include sediment laid down during the past 200 years, and 'long cores', which penetrate the entire organic layer at the bottom of a lake and are usually 3-5 m long. Short cores are used in acid rain studies to trace the pH history of lakes during the past 200 years using geochemical and diatom inferred pH methodologies. Lake sediment long cores include material laid down since the last Ice Age and can be used to describe the geochemical, palynological and diatom history of lake catchment areas.

Data from Ontario and Nova Scotia demonstrate that spatial correlations and temporal markers from lake to lake can be established by these methods. For example, a ragweed (Ambrosia Spp.) pollen layer in Ontario and a Plantago Spp. pollen layer in Nova Scotia have both been used extensively to date the chemical stratigraphy of lake sediment cores collected from these areas.

Lake sediment core case histories also describe at least four types of Canadian acid lakes. Some of these lakes are naturally acid and others have become acid due to acid rain, pollution and/or environmental degradation. The geochemistry of post-Ambrosia environmental disturbances has been noted from lakes near smelters in Ontario and from the post-Plantago layer at Chocolate Lake, Nova Scotia. Dramatic increases in baseline metal values (e.g. by Pb due to automobiles, Cu due to modern plumbing, V due to home heating oil, etc.) are observed in most lake sediment cores. Cores from some Nova Scotia lakes include a geochemically distinct 'backhoe' horizon caused by accelerated bedrock weathering due to excavation and construction activities in catchment areas about 40 years ago. Long-term changes in such elements as zinc, copper and lead have been noted as the lake basins mature with time.

All post-glacial lakes in central and eastern Canada show an increased organic content with time from ca. 10,500 to 9,000 radiocarbon years before present (RYBP). This increase is a consequence of decreased soil erosion and increasing vegetation as post-glacial warming permitted a re-establishment of closed boreal forests. In Nova Scotia, lake sediment cores record a distinct climatic change to a warm, dry maximum at ca. 3500-5500 RYBP, the xenothermal interval. Reduced precipitation and runoff during this time lowered flushing rates and increased organic sedimentation. The possible effects of future global warming can be inferred from such data on previous periods of global warming recorded in long cores.

Lake sediment short and long cores provide a means to establish both a spatial and temporal baseline datum for geochemical mapping. Short cores may provide detailed evidence for increased acidification and/or input of elements due to man's activities during the past several hundred years. Long lake sediment cores, taken from all ecological zones in the world, would provide unique spatial and temporal information pertinent to the preparation of a world geochemical map.

The recent commitment to a world geochemical map, Project 259 of the International Geological Correlation Program (IGCP), means that exploration geochemistry is globally coming of age. The production of a world geological map with other thematic maps places the earth science community, including the mining industry, in the forefront of the environmental issue. The next meeting of IGCP Project 259 is being held in Prague, Czechoslovakia, this month and many of these issues will be discussed.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 110

LITHOSTRATIGRAPHIC REVISION OF THE UPPER CARBONIFEROUS TO LOWER PERMIAN STRATA OF THE CUMBERLAND AND PICTOU GROUPS IN THE CUMBERLAND BASIN, NOVA SCOTIA, AND REGIONAL IMPLICATIONS FOR THE MARITIMES BASIN[1]

R. J. Ryan, R. C. Boehner and J. H. Calder

The upper Paleozoic strata exposed in the Cumberland Basin, part of the larger regional Maritimes Basin of Atlantic Canada, have been considered as classic Carboniferous sections since their original description in the mid 1800s (Joggins Section). Stratigraphic nomenclature applied to the upper Carboniferous strata, which locally exceed a thickness of 7 km, is problematic due to numerous poorly defined or informal units and a confusing mixture of litho-, bio-, and chrono-stratigraphic terminology. The Cumberland Basin is a key area in the regional nomenclature because it contains the type sections of the Cumberland and Pictou groups, and well exposed sections of strata traditionally assigned to the Riversdale Group (abandoned and constituents incorporated into the Cumberland Group) and Canso Group (abandoned and replaced by the Mabou Group, after Belt, 1964 and 1965).

The constituent formations of the Cumberland and Pictou groups include in ascending order: Cumberland Group, (1) Claremont and (2) Boss Point, (both formerly assigned to the abandoned Riversdale Group); (3) Polly Brook (new), (4) Joggins (redefined), (5) Springhill Mines (new), (6) Ragged Reef (new), (7) Malagash (new); and Pictou Group, (8) Balfron (new), (9) Tatamagouche (new), and (10) Cape John (redefined). The resulting revision of the groups is based upon formal formation subdivisions and utilizes lithostratigraphic criteria such as: composition, occurrence of coal and related strata, predominant colour and grain size, vertical and lateral variation, and stratigraphic relationships. Within the context of the Cumberland Basin the revisions are modest relocations of group boundaries in the type sections: (1) Pictou Group base shifted upsection to exclude the strata of the Malagash Formation, and (2) the repatriation of the Boss Point and Claremont formations to the base of the Cumberland Group. The revised Cumberland Group conformably and unconformably overlies strata of the Mabou Group (Belt, 1964 and 1965) and includes all of the grey (dominated) coal-bearing strata in the basin. It also includes greybeds that were previously assigned to the base of the Pictou Group in the type section. Strata previously assigned to all or portions of the Morien Group, Stellarton Group (Formation) and Petitcodiac Group could be re-assigned to the Cumberland Group and would avoid the current synonomy at the group level. The revised Pictou Group comprises all of the redbed dominated, non-coal-bearing strata above the the Cumberland Group and regionally could include the Pictou Group redbeds in the Gulf of St. Lawrence as well as most of the newly introduced formations of the Prince Edward Island Group. The proposed lithostratigraphic subdivisions (new and revised) and group assignment criteria will facilitate regional correlation and basin analysis within the Maritimes Basin.

1 Poster presented at the Atlantic Geoscience Society annual symposium, Amherst, Nova Scotia, February 1991; modified abstract of a paper in press, Canadian Society of Petroleum Geologists Bulletin

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 111

GEOLOGY, GEOCHEMISTRY, AND EXPLORATION APPLICATIONS FOR THE PERMO-CARBONIFEROUS REDBED COPPER DEPOSITS OF THE CUMBERLAND BASIN, NOVA SCOTIA, CANADA[1]

R. J. Ryan, R. C. Boehner, R. R. Stea and P. J. Rogers

The greatest number of mineral occurrences in the Cumberland Basin, Nova Scotia, are the Cu-Ag redbed (Nacimiento) type associated with the red and grey continental sandstone and shale of the Upper Carboniferous - Lower Permian Pictou Group. The Cu mineralization occurs as chalcocite with pyrite and bornite near the red to grey boundaries within the strata. The depth (up to 440 m) of the mineralization suggests that it is not shallow supergene (<20 m) as previously proposed.

The coarse-grained redbeds are of diagenetic origin. Geochemical studies of till, stream sediment and rocks indicate that Cu may have been leached from the redbeds, probably during a Late Permian-Early Triassic reddening event. Oxygenated groundwater may have carried the Cu in solution from the redbeds to reducing sites, either carbon-rich lags within the channel sandstones or at the interface with reducing basinal waters, where the Cu was precipitated at a solution front.

The association of extensive negative geochemical Cu anomalies with redbeds containing numerous Cu occurrences delineates potential areas of exploration for mineralization of this type. The common association of Ag and Au with these occurrences enhances their attractiveness as exploration targets.

1 In: Sediment-hosted Stratiform Copper Deposits, eds. R. W. Boyle, A. C. Brown, C. W. Jefferson, E. C. Jowett and R. V. Kirkham; Geological Association of Canada, Special Paper 36, p. 245-256.

Mines and Minerals Branch, Report of Activities 1990;
Nova Scotia Department of Mines and Energy,
Report 91-1, p. 112

INTERPRETATION OF TILL GEOCHEMICAL DATA IN NOVA SCOTIA, CANADA, USING MAPPED TILL UNITS, MULTI-ELEMENT ANOMALY PATTERNS, AND THE RELATIONSHIP OF TILL CLAST GEOLOGY TO MATRIX GEOCHEMISTRY[1]

R. G. Turner[2] and R. R. Stea

The significance of multi-element (Cu, Pb, Zn, Cd, Ag, Sn and W) till anomalies in selected areas of northern mainland Nova Scotia was examined by: (1) comparing local element levels for mapped till types with regional element levels calculated from a combination of all till types; (2) examining the spatial pattern of multi-element anomalies in selected study areas; and, (3) assessing the inter-element associations and element-clast geology associations for each major till type. Large areas of single-element anomalies were outlined using the 75th and 95th percentile contours from the regional data set. Local case studies (Wentworth Station, Scotsburn and Ohio) were selected within these regionally anomalous areas.

At Wentworth Station till matrix geochemistry and clast correlations identify Cobequid Highlands granitic rocks as the host for Sn-W minerals producing till anomalies. Cassiterite has been identified in the Cobequid Highlands Massif. The Sn-W till anomalies overlying Carboniferous sedimentary rocks north of the Cobequid Highlands are related to northward glacial dispersal and/or Carboniferous paleoplacer deposition.

At Scotsburn the proximity of multi-element base metal till anomalies to known Pb-Zn and Cu-Ag mineral occurrences, and primary metal associations like Pb and Zn, suggest that the till anomalies are significant.

Within the Ohio study area one group of base metal till anomalies is related to a known copper belt. A second group of tungsten-base metal till anomalies may reflect an undiscovered polymetallic mineral occurrence hosted by volcanic rocks of the Antigonish Highlands. Elevated tungsten levels are correlated with felsic volcanic clasts in stony tills of the area.

---

1 In: Journal of Geochemical Exploration, v. 37, p. 225-254

2 Maritime Groundwater Inc., 184 Portland Street, Dartmouth, Nova Scotia B2Y 1J4

APPENDIX 1

NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY

PUBLICATIONS AND MAPS FOR SALE

ACTS

Mineral Resources Act and Regulations, by Nova Scotia Department of Mines and Energy, 1990. ($10.00)

Coal Mines Regulation Act, by Nova Scotia Department of Mines and Energy, 1967, 143 pages. ($3.00)

Petroleum Resources Act, by Nova Scotia Department of Mines and Energy, 1984. ($0.75)

Gypsum Mining Income Tax Act cited as R.S.N.S., 1967, Chapter 122, 1979, 9 pages. ($1.00)

An Act Respecting Exploration for the Underground Storage of Gas, by Nova Scotia Department of Mines and Energy, 1970, 6 pages. ($1.00)

BULLETINS

Comprehensive reports on geological or related subjects on a regional basis.

Bulletin 01 Port Hawkesbury Project - Geology, Geochemistry and Groundwater Investigations of Southwest Inverness and Richmond Counties, Nova Scotia, by F. S. Shea and J. D. Wallace, 1962, 73 pages, 5 maps. ($2.00)

Bulletin 02 (Part 1) Limestones and Dolomites of Nova Scotia, Part I - Cape Breton Island, by F. S. Shea and D. A. Murray, 1969, 300 pages, 1 map. ($4.00)

Bulletin 02 (Part 2) Limestones and Dolomites of Nova Scotia, Part II - Antigonish, Guysborough, Pictou, and Cumberland Counties, by D. A. Murray, 1975, 155 pages. ($6.50)

Bulletin 03 Assessment of Peat Moss Occurrences in Guysborough, Antigonish, Pictou, Colchester and Cumberland Counties, Nova Scotia, by D. R. Sutherland and F. S. Shea, 1976, 301 pages. ($7.00)

Bulletin 04 Barite, Celestite and Fluorite in Nova Scotia, by G. W. Felderhof, 1978, 463 pages, 200 Figures, 12 Tables. ($13.00)

Bulletin 05 Salt and Potash Resources in Nova Scotia, by R. C. Boehner, 1986, 346 pages, 8½" x 11" format, includes NSDME Map 83-3, scale 1:500 000. ($15.00)
(Microfiche $5.00)

Bulletin 06 Evaluation of Nova Scotia's Peatland Resources, by A. R. Anderson and W. A. Broghm, 1988, 109 pages and 3 maps, scale 1:250 000. ($15.00)

CONTRIBUTION SERIES

Any geoscience documents by Nova Scotia Department of Mines and Energy staff published externally.

CS 80-001 Paleozoic Volcanic Rocks of Nova Scotia, by J. D. Keppie and J. Dostal, 1980, 8 pages; *in* Proceedings: "The Caledonides in the U.S.A." I.G.C.P. Project 27: Caledonide Orogen. ($1.00)

CS 80-002 Granitoid and other Plutonic Rocks of Nova Scotia, by D. B. Clarke, S. M. Barr and H. V. Donohoe, 1980, 10 pages; *in* Proceedings: "The Caledonides in the U.S.A." I.G.C.P. Project 27: Caledonide Orogen. ($1.00)

CS 81-001 Determination of Gold in Natural Waters at the Parts-per-Trillion (pg cm^{-3}) level, by R. R. Brooks, A. K. Chatterjee and D. E. Ryan; *in* Chemical Geology, 33, 1981; 7 pages. ($1.00)
(Microfiche $1.00)

CS 81-002 Plate Tectonics and Tectonic Mapping, by J. Duncan Keppie, 1981; *in* Episodes, vol. 1981, no. 4, 1981; 4 pages. (FREE)

CS 82-001 Observations on the Ichnology of the Meguma Group (?Cambro-Ordovician) of Nova Scotia, by R. K. Pickerill and J. D. Keppie, 1981; *in* Maritime Sediments and Atlantic

Geology, 17, 1981; 9 pages. ($1.50)
(Microfiche $1.00)

CS 82-002 A Rapid Method for the Determination of Gold and Silver in Sulfide Ores and Rocks, by R. R. Brooks, J. Holzbecher, D. E. Ryan, H. F. Zhang and A. K. Chatterjee, 1981; *in* Atomic Spectroscopy, vol. 2, no. 5, 1981; 4 pages. (FREE)
(Microfiche only $1.00)

CS 82-003 Geochemistry and the Distribution of Uranium and Thorium in the Granitoid Rocks of the South Mountain Batholith, Nova Scotia, by A. K. Chatterjee and G. K. Muecke; *in* Uranium in Granites; Geological Survey of Canada, Paper 81-23, p. 11-17, 1982; 17 pages. ($1.50)
(Microfiche $1.00)

CS 82-004 The Minas Geofracture, by J. D. Keppie, 1982; *in* Geological Association of Canada, Special Paper 24, 18 pages. ($2.00)
(Microfiche $1.00)

CS 82-005 The Distribution of Gold in Rocks and Minerals of the Meguma Group of Nova Scotia, Canada, by R. R. Brooks, A. K. Chatterjee, P. K. Smith, D. E. Ryan and H. F. Zhang; *in* Chemical Geology, vol. 35, 1982; 9 pages. (FREE)
(Microfiche only $1.00)

CS 83-001 A Multivariate Approach to Geochemical Distinction Between Tin-specialized and Uranium-specialized Granites of Southern Nova Scotia, by A. K. Chatterjee, D. F. Strong, and G. K. Muecke; *in* Canadian Journal of Earth Sciences, vol. 20, 1983. ($1.50)
(Microfiche $1.00)

CS 83-002 Uranium and Thorium in Paleozoic Rhyolites of Nova Scotia, by J. Dostal, C. Dupuy, and J. D. Keppie; *in* Canadian Journal of Earth Sciences, vol. 20, no. 2, 1983. ($1.50)
(Microfiche $1.00)

CS 84-001 Proceedings of the Deformation Study Group, Caledonide Orogen Project, by J. D. Keppie, D. G. Gee, D. Roberts, D. Powell, M. D. Max, P. Osberg, A. Pique, and J. P. Lecorche; *in* Regional Trends in the Geology of the Appalachian-Caledonian-Hercynian-Mauritanide Orogen, ed. P. E. Schenk, 1983, p. 275-278. ($1.50)
(No Microfiche)

CS 84-002 Times of Deformation in the Canadian Appalachians, by J. D. Keppie, P. St. Julien, C. Hubert, J. Beland, B. Skidmore, L. R. Fyffe, A. A. Ruitenberg, S. R. McCutcheon, H. Williams and J. Bursnall; *in* Regional Trends in the Geology of the Appalachian-Caledonian-Hercynian-Mauritanide Orogen, ed. P. E. Schenk, 1983, p. 307-313. ($1.50)
(No Microfiche)

CS 84-003 Petrology and Geochemistry of Devono-Carboniferous Volcanic Rocks in Nova Scotia, by J. Dostal, J. D. Keppie and C. Dupuy; *in* Maritime Sediments and Atlantic Geology, vol. 19, 1983, p. 59-71. ($1.50)
(No Microfiche)

CS 84-004 The Appalachian Collage, by J. D. Keppie; *in* The Caledonide Orogen - Scandinavia and Related Areas, eds. D. G. Gee and B. A. Sturt, 1985, p. 1217-1226. ($2.00)
(Microfiche $1.00)

CS 84-005 Mining in Nova Scotia - Past and Present, by H. V. Donohoe, Jr.; *in* CIM Directory 1984, p. 1-24. ($1.50)
(Microfiche $1.00)

CS 84-006 Discriminant and Factor Analysis of Geochemical Data from Granitoid Rocks Hosting the Millet Brook Uranium Mineralization, South Mountain Batholith, Nova Scotia, by A. K. Chatterjee and D. F. Strong; *in* Uranium, vol. 1, 1984, p. 289-305. ($3.00)
(No Microfiche)

CS 85-002 Cambrian Volcanism in Nova Scotia, Canada, by J. B. Murphy, K. Cameron, J. Dostal, J. D. Keppie and A. J. Haynes; *in* Canadian Journal of Earth Sciences, vol. 22, no. 4, 1985, p. 599-606. ($1.50)
(Microfiche $1.00)

CS 86-001 The Petrology, Geochemistry, and Economic Potential of the Musquodoboit Batholith, Nova Scotia, by M. A. MacDonald and D. B. Clarke; *in* Canadian Journal of Earth Sciences, vol. 22, 1985, p. 1633-1642. ($1.50)
(Microfiche $1.00)

CS 86-002 Upper Carboniferous Strata of the Tatamagouche Syncline, Cumberland Basin, Nova Scotia, by R. J. Ryan; *in* Current Research, Part B, Geological Survey of Canada, Paper 85-1B, p. 481-490, 1985. ($2.00)
(Microfiche $1.00)

CS 86-003 Review of some Chemical and Mineralogical Characteristics of Granitoid Rocks Hosting Sn, W, U, Mo Deposits in Newfoundland and Nova Scotia, by A. K. Chatterjee and D. F. Strong; *in* High Heat Production (HHP) Granites, Hydrothermal Circulation and Ore Genesis, papers presented at the conference organized by The Institution of Mining and Metallurgy, St. Austell, Cornwall, England, September 22-25, 1985, p. 489-516. ($2.00)
(No Microfiche)

CS 86-004 Contributions to the Geology of the Meguma Terrane, Nova Scotia, ed. J. D. Keppie; a special issue of Maritime Sediments and Atlantic Geology, vol. 22, no. 1, 1986, 135 pages. ($10.00)
(No Microfiche)

CS 87-001 Rb-Sr Isotopic Data from Three Suites of Igneous Rocks, Cape Breton Island, Nova Scotia, by J. D. Keppie and A. N. Halliday; *in* Maritime Sediments and Atlantic Geology, vol. 22, 1986, p. 162-171. ($1.50)
(Microfiche $1.00)

CS 87-002 Fossil Myriapod Trails in the Permo-Carboniferous Strata of Northern Nova Scotia, Canada, by R. J. Ryan; *in* Maritime Sediments and Atlantic Geology, vol. 22, 1986, p. 156-161. ($1.50)
(Microfiche $1.00)

CS 87-003 Two Rb-Sr Whole Rock Isochrons from Plutons in the Cobequid Highlands, Nova Scotia, Canada, by H. V. Donohoe, A. N. Halliday and J. D. Keppie; *in* Maritime Sediments and Atlantic Geology, vol. 22, 1986, p. 148-154. ($1.50)
(Microfiche $1.00)

CS 87-004 Barytes, the "No-Wait" Agent, by J. H. Fowler; *in* CIM Bulletin, vol. 79, 1987, no. 889, p. 38-42. (FREE)
(Microfiche $1.00)

CS 87-006 Anorthosites and Gabbroic Bodies in Northern Cape Breton Island, Nova Scotia, by C. Dupuy, J. Dostal, P. K. Smith and J. D. Keppie; *in* Maritime Sediments and Atlantic Geology, vol. 22, no. 2, 1986, p. 136-147. (FREE)
(Microfiche $1.00)

CS 87-007 Sedimentology, Structure, and Metallogeny of the Goldenville Formation, Meguma Terrane, Isaacs Harbour, Nova Scotia, by J. D. Keppie; *in* Geological Society of America Centennial Field Guide, Northeastern Section, 1987, p. 433-439. (FREE)

CS 87-008 Development Potential for Offshore Placer and Aggregate Resources of Nova Scotia, Canada, by C. K. Miller and J. H. Fowler; *in* Marine Mining, vol. 6, 1987, p. 121-139. (FREE)

CS 87-009 Polyphase Late Paleozoic Tectonothermal Evolution of the Southwestern Meguma Terrane, Nova Scotia: Evidence from $^{40}Ar/^{39}Ar$ Mineral Ages, by R. D. Dallmeyer and J. D. Keppie; *in* Canadian Journal of

Earth Sciences, vol. 24, 1987, p. 1242-1254. (FREE)
(Microfiche $1.00)

CS 87-010 Age of the Five Islands Formation, Nova Scotia, and the Deglaciation of the Bay of Fundy, by R. R. Stea and D. M. Wightman; *in* Quaternary Research, vol. 27, 1987, p. 211-219. ($2.00)
(Microfiche $1.00)

CS 87-011 Lithophile Elements and Exploration Using Centre-Lake Bottom Sediments from the East Kemptville Area, Southern Nova Scotia, Canada, by P. J. Rogers and R. G. Garrett; *in* Journal of Gecchemical Exploration, vol. 28, 1987, p. 467-478. (FREE)

CS 87-012 Catchment Basin Analysis Applied to Surficial Geochemical Data, Cobequid Highlands, Nova Scotia, by G. F. Bonham-Carter, P. J. Rogers and D. L. Ellwood; *in* Journal of Geochemical Exploration, vol. 29, 1987, p. 259-278. (FREE)

CS 87-013 Late Paleozoic Sedimentation and Basin Development Adjacent to the Cobequid Highlands Massif, Eastern Canada, by R. J. Ryan, J. H. Calder, H. V. Donohoe, Jr., and R. Naylor; *in* Sedimentary Basins and Basin Forming Mechanisms, edited by C. Beaumont and A. J. Tankard, Canadian Society of Petroleum Geologists, Memoir 12, 1987, p. 311-317. (FREE)

CS 87-014 Dating Transcurrent Terrane Accretion: An example from the Meguma and Avalon Composite Terranes in the Northern Appalachians, by J. D. Keppie and R. D. Dallmeyer; *in* Tectonics, vol. 6, no. 6, December 1987, p. 831-847. (FREE)

CS 88-001 Metasomatic Origin of Spessartine-Rich Garnet in the South Mountain Batholith, Nova Scotia, by D. Kontak and M. C. Corey; *in* Canadian Mineralogist, vol. 26, 1988, p. 315-334. ($1.00)
(Microfiche $1.00)

CS 88-002 Gypsum in Canada - Present Status and Future Developments, by J. H. Fowler and G. C. Adams; *in* Mining Engineering, February 1988, p. 120-124. (FREE)
(No Microfiche)

CS 88-003 U-Pb and Rb-Sr Geochronology of the Wedgeport Granitoid Pluton, Southwestern Nova Scotia, by R. F. Cormier, J. D. Keppie and A. L. Odom; *in* Canadian Journal of Earth Sciences, vol. 25, 1988, p. 255-261. (FREE)
(No Microfiche)

CS 88-004 Silurian-Permian Palaeocontinental Reconstructions and Circum-Atlantic Tectonics, by D. V. Kent and J. D. Keppie; *in* Caledonian-Appalachian Orogen, Geological Society Special Publication no. 38, 1988, p. 469-480. (FREE)
(No Microfiche)

CS 88-006 Contributions on the Geology of Granitoid and Host Rocks, Meguma Terrane, Nova Scotia, edited by D. J. Kontak and S. M. Barr; a special issue of Maritime Sediments and Atlantic Geology, vol. 24, no. 1, 1988, 121 pages. ($10.00)
(No microfiche)

CS 89-001 Anatomy of a Telescoped Pull-Apart Basin: An Example from the Cambro-Ordovician Rocks in the Antigonish Highlands of Nova Scotia, by J. D. Keppie and J. B. Murphy; *in* Maritime Sediments and Atlantic Geology, vol. 24, 1988, p. 123-138. (FREE)
(No Microfiche)

CS 89-002 Carbonate Buildups of the Gays River Formation, Lower Carboniferous Windsor Group, Nova Scotia, by R. C. Boehner, P. S. Giles, D. A. Murray and R. J. Ryan; *in* Reefs, Canada and Adjacent Area, Canadian Society of

Petroleum Geologists, Memoir 13, 1989, p. 609-621. (FREE)
(No Microfiche)

CS 89-003 Carbonate Buildups of Windsor Group Major Cycle 2: Maxner and Miller Limestones, Miller Creek Formation and Mosher Road Member, Elderbank Formation and B_2 Limestone, Nova Scotia, by R. C. Boehner; *in* Reefs, Canada and Adjacent Area, Canadian Society of Petroleum Geologists, Memoir 13, 1989, p. 600-608. (FREE)
(No Microfiche)

CS 89-004 A Lacustrine Limestone Mound (Algal Reef) in the Wilkie Brook Formation (Horton Group), Cape George Area, Northeastern Mainland Nova Scotia, by R. C. Boehner and B. E. MacBeth; *in* Reefs, Canada and Adjacent Area, Canadian Society of Petroleum Geologists, Memoir 13, 1989, p. 626-630. (FREE)
(No Microfiche)

CS 89-005 Carbonate Bioherms in the Kennetcook and Herbert River Limestone Members, Upper Part of the Windsor Group, Central Mainland Nova Scotia, by R. C. Boehner, R. J. Horne, R. J. Ryan; *in* Reefs, Canada and Adjacent Area, Canadian Society of Petroleum Geologists, Memoir 13, 1989, p. 622-625. (FREE)
(No Michrofiche)

CS 89-006 Northern Appalachian Terranes and Their Accretionary History, by J. D. Keppie; *in* Geological Society of America, Special Paper 230, 1989, p. 159-192. (FREE)
(No Microfiche)

CS 89-007 Variation in Drumlin Orientation, Form and Stratigraphy Relating to Successive Ice Flows in Southern and Central Nova Scotia, by R. R. Stea and Y. Brown; *in* Sedimentary Geology, vol. 62, 1989, p. 223-240. (FREE)
(No Microfiche)

CS 89-008 Downhole Geophysics as an Aid to the Interpretation of an Evaporite Sequence: Examples from Nova Scotia, by D. C. Carter; *in* CIM Bulletin, vol. 82, no. 925, p. 58-64. (FREE)
(No Microfiche)

CS 89-009 Deglaciation Environments and Evidence for Glaciers of Younger Dryas Age in Nova Scotia, Canada, by Rudolph R. Stea and Robert J. Mott; *in* BOREAS, vol. 18, p. 188. (FREE)
(No Microfiche)

CS 89-010 Petrology, Rock-Eval and Facies Analyses of the McLeod Coal Seam and Associated Beds, Pictou Coalfield, Nova Scotia, Canada, by J. Paul, W. Kalkreuth, R. Naylor and W. Smith; *in* Atlantic Geology, vol. 25, 1989, p. 81-92. (FREE)
(No Microfiche)

CS 89-011 Sulphur Isotopic Composition of Sulphides from the Beaver Dam and other Meguma Group Hosted Gold Deposits, Nova Scotia: Implication for Genetic Models, by D. J. Kontak and P. K. Smith; *in* Canadian Journal of Earth Sciences, vol. 26, no. 8, 1989, p. 1617-1629. (FREE)
(No Microfiche)

CS 90-001 The East Kemptville Topaz-Muscovite Leucogranite, Nova Scotia: Geological Setting and Whole-Rock Geochemistry, by Daniel J. Kontak; *in* Canadian Mineralogist, vol. 28, 1990, p. 787-825. (FREE)
(No Microfiche)

CS 90-004 Interpretation of Till Geochemical Data in Nova Scotia, Canada, Using Mapped Till Units, Multi-Element Anomaly Patterns, and the Relationship of Till Clast Geology to Matrix Geochemistry, by R. G. Turner and R. R. Stea; *in* Journal of Geochemical Exploration, vol. 37, 1990, p. 225-254. (FREE)
(No Microfiche)

CS 90-006 Geochemistry of Late Proterozoic Basaltic Rocks from Southeastern

Cape Breton Island, Nova Scotia, by J. Dostal, J. D. Keppie and J. B. Murphy; *in* Canadian Journal of Earth Sciences, vol. 27, 1990, p. 619-631. (FREE)
(No Microfiche)

CS 90-007 Characteristics of REE and Other Trace Elements in Response to Successive and Superimposed Metasomatism Within a Portion of the South Mountain Batholith, Nova Scotia, Canada, by Michael C. Corey and A. K. Chatterjee; *in* Chemical Geology, vol. 85, 1990, p. 265-285. (FREE)
(No Microfiche)

CS 90-008 Exploration Drilling of Evaporites: Procedures Developed in Eastern Canada, by D. C. Carter and J. P. Anderle; *in* CIM Bulletin, July 1990, p. 103-112. (FREE)
(No Microfiche)

CS 90-009 Seismic Modelling of Porosity Within the Jurassic Age Carbonate Bank, Offshore Nova Scotia, by Paul J. Harvey and D. Jack MacDonald; *in* Canadian Journal of Exploration Geophysics, vol. 26, nos. 1 and 2, 1990, p. 54-71. (FREE)
(No Microfiche)

CS 90-010 Fluorescence Properties of Alginite-rich Oil Shales from the Stellarton Basin, Canada, by W. Kalkreuth, R. Naylor, K. Pratt and W. Smith; *in* Fuel, vol. 69, February 1990, p. 139-144. (FREE)
(No Microfiche)

CS 90-011 Metallogenic Domains and Their Reflection in Regional Lake Sediment Surveys from the Meguma Zone, Southern Nova Scotia, Canada, by Peter J. Rogers, Amulaya K. Chatterjee and Jeffrey W. Aucott; *in* Journal of Geochemical Exploration, vol. 39, 1990, p. 153-174. (FREE)
(No Microfiche)

CS 90-012 A Sulphur Isotope Study of Main-Stage Tin and Base Metal Mineralization at the East Kemptville Tin Deposit, Yarmouth County, Nova Scotia, Canada: Evidence for Magmatic Origin of Metals and Sulfur, by Daniel J. Kontak; *in* Economic Geology, vol. 85, 1990, p. 399-407. (FREE)
(No Microfiche)

CS 91-001 The East Kemptville Topaz-Muscovite Leucogranite, Nova Scotia. II. Mineral Chemistry, by Daniel J. Kontak; *in* Canadian Mineralogist, vol. 29, 1990, p. 153-174. (FREE)
(No Microfiche).

CS 91-002 Peat Formation in a Westphalian B Piedmont Setting, Cumberland Basin, Nova Scotia: Implications for the Maceral-Based Interpretation of Rheotrophic and Raised Paleomires, by John H. Calder, Martin R. Gibling and Prasanta K. Mukhopadhyay; *in* Bulletin de la Societe Geologique de France, 1991, t.162, no. 2, p. 283-298. (FREE)
(No Microfiche)

CS 91-003 Geochronological Evidence for Multiple Tectonothermal Overprinting Events in the East Kemptville Muscovite - Topaz Leucogranite, Yarmouth County, Nova Scotia, Canada, by D. J. Kontak and R. F. Cormier; *in* Canadian Journal of Earth Sciences, vol. 28, no. 2, 1991, p. 209-224. (FREE)
(No Microfiche)

CS 91-004 The Role of Fluids in the Late-Stage Evolution of the South Mountain Batholith, Nova Scotia: Further Geochemical and Oxygen Isotopic Studies, by Daniel J. Kontak, Robert Kerrich and David F. Strong; *in* Atlantic Geology, vol. 27, 1991, p. 29-47. (FREE)
(No Microfiche)

ECONOMIC GEOLOGY SERIES

Reports about a commodity of economic or potential economic interest on any geographical basis, regional or local.

EGS 74-01 Geology and Trace Element Studies of Manganese Occurrences in Nova Scotia, by D. G. Bishop and J. D. Wright, 1974, 255 pages. ($7.50)

EGS 75-01 Iron Deposits of Nova Scotia, by J. D. Wright, 1975, 154 pages, 1 map. ($6.00)

EGS 89-01 Properties and Uses of Nova Scotia Clays and Shales, by Susan Gouthro, 1989, 288 pages. ($20.00) (Microfiche $3.00)

EGS 90-01 Diatomaceous Earth Occurrences in Nova Scotia, by A. R. Anderson, 1990, 132 pages. ($15.00) (Microfiche $3.00)

EGS 90-02 Filler and Extender Minerals in Nova Scotia, by Peter Luke, 1990, 64 pages. ($6.00) Microfiche $2.00)

EGS 90-03 Oil Shale Resources of Nova Scotia, by W. D. Smith and R. D. Naylor, 1990, 73 pages. ($12.00) (Microfiche $2.00)

INFORMATION CIRCULARS

Free, promotional pamphlets on geological or related subjects intended for the general public.

No. 01 Directory of Goods and Services for Exploration Companies, Nova Scotia Department of Mines and Energy, February 1986, revised April 1988. (FREE)

No. 02 Mineral Rights, Landowners, and Mineral Exploration, Nova Scotia Department of Mines and Energy, February 1986. (FREE)

No. 03 A Walking Tour of Rocks, Minerals, and Building Stones in Downtown Halifax, Nova Scotia Department of Mines and Energy, April 1986. (FREE)

No. 04 Nova Scotia Gold, Nova Scotia Department of Mines and Energy, May 1986. (FREE)

No. 07 A Walking Tour of Rocks, Minerals and Landforms of Point Pleasant Park, Nova Scotia Department of Mines and Energy, June 1986. (FREE)

No. 08 Staking Claims in Nova Scotia, Nova Scotia Department of Mines and Energy, 1987. (FREE)

No. 09 A Walking Tour of Rocks, Minerals and Landforms of Peggy's Cove, by Anita Sampson and Howard Donohoe, 1987. (FREE)

No. 10 A Walking Tour of Rocks, Minerals and Building Stones along Spring Garden Road, Halifax, by Katherine Bishop, Anne Stevenson, Martha Devanney and Howard Donohoe, 1987. (FREE)

No. 11 A Walking Tour of Rocks, Minerals, and Landforms of Victoria Park, Truro, by Howard Donohoe and Martha Devanney, 1987. (FREE)

No. 12 Building Stone in Nova Scotia, by G. B. Dickie, 1988. (FREE)

No. 14 Silica in Nova Scotia, by R. H. MacDonald, 1988. (FREE)

No. 15 Barite, Celestite and Fluorite in Nova Scotia, by J. H. Fowler, 1988. (FREE)

No. 16 Gypsum and Anhydrite in Nova Scotia, by G. C. Adams, 1988. (FREE)

No. 17 Diatomite in Nova Scotia, by A. R. Anderson, 1988. (FREE)

No. 18 Peat Moss in Nova Scotia, by A. R. Anderson, 1988. (FREE)

No. 19 Salt in Nova Scotia, by G. Prime, 1988. (FREE)

No. 21 A Walking Tour of Rocks, Minerals, and Building Stones of Prince Street, Truro, by Jo-Anne Goodwin *et al.*, August 1988. (FREE)

No. 22 Land Use Policy Development Project, by David B. Hopper and Andrew J. Kendall, November 1988. (FREE)

INFORMATION SERIES

No. 03 Program and Summaries, Fourth Annual Open House and Review of Activities of the Mineral Resources Division, by Nova Scotia Department of Mines and Energy, 1980, 106 pages. (OUT OF PRINT)
(Microfiche only $1.00)

No. 04 Program and Summaries, Fifth Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1981, 51 pages. (OUT OF PRINT)
(Microfiche only $1.00)

No. 05 Program and Summaries, Sixth Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1982, 69 pages. ($1.00)
(Microfiche $1.00)

No. 06 Program and Summaries, Seventh Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1983, 123 pages. (OUT OF PRINT)
(Microfiche only $2.00)

No. 07 Program and Summaries, Eighth Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1984, 115 pages. ($2.00)
(Microfiche $1.00)

No. 08 Coal in Nova Scotia, by J. H. Calder, 1985, 79 pages. ($5.00)

No. 09 Program and Summaries, Ninth Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1985, 136 pages. ($3.00)
(Microfiche $1.50)

No. 10 Petroleum Wells and Drillholes with Petroleum Significance, Onshore Nova Scotia, compiled by P. McMahon, G. Short, and D. Waler, January 1986, 194 pages. ($10.00)
(Microfiche $2.00)

No. 11 Surface Petroleum Shows, Onshore Nova Scotia, compiled by Gayle Short, March 1986, 33 pages. ($5.00)
(Microfiche $1.00)

No. 12 Program and Summaries, Tenth Annual Open House and Review of Activities, by Nova Scotia Department of Mines and Energy, 1986, 205 pages. ($5.00)
(Microfiche $2.00)

NOTE: Program and Summaries will continue as part of our Report Series.

No. 13 Gold in Nova Scotia, by Jennifer Bates, 1987, 35 pages. ($5.00)

No. 14 Reflection Seismic Coverage of Onshore and Nearshore Nova Scotia 1942-1987, compiled by P. G. McMahon, 1988, 34 pages, 3 maps in back pocket. ($5.00)

No. 19 Nova Scotia Dimension Stone for Designers, Developers and Quarriers, 1989, 24 pages. (FREE)

MAPS

Preliminary Map 78-1 Geology Map of the Cobequid Highlands, by H. V. Donohoe and P. I. Wallace, scale 1:125 000. ($3.50)

Map 81-01 Pleistocene Geology and Till Geochemistry, Central Nova Scotia, (Sheet 4; Sheets 1, 2 and 3 are in Paper 79-4), by R. R. Stea and J. H. Fowler, scale 1:100 000 ($3.50)

Map 82-01 Pleistocene Geology and Till

Geochemistry of South Central Nova Scotia (Sheet 6), by R. R. Stea, scale 1:100 000 (Sheet 5 is in OFR 555). ($3.50)

Map 82-02 Antigonish Basin, by R. C. Boehner and P. S. Giles, scale 1:50 000. ($3.00)

Map 82-03 Eureka Area, by P. S. Giles, scale 1:50 000. ($3.00)

Map 82-04 Shubenacadie and Musquodoboit Basins, by P. S. Giles and R. C. Boehner, scale 1:50 000. ($5.00)

Map 82-05 Geology Map of the Northern Antigonish Highlands, Nova Scotia, by J. B. Murphy, J. D. Keppie and A. Hynes, scale 1:50 000. ($4.00)

Map 82-06 Advocate Harbour-Port Granville Region, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. ($8.00)

Map 82-07 Parrsboro-Five Islands Region, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. ($8.00)

Map 82-08 Economy River-Folly Lake Region, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. ($8.00)

Map 82-09 Debert-Mt. Thom Region, by H. V. Donohoe, Jr., and P. I. Wallace, scale 1:50 000. ($8.00)

NOTE: Maps 82-6 to 82-9 may be purchased individually or as a set for **$25.00**.

Map 82-10 Pleistocene Geology and Till Geochemistry of Southwestern Nova Scotia (Sheets 7 and 8), by R. R. Stea and D. R. Grant, scale 1:100 000. (Sheet 9 is in GSC Map 163A of Paper 85-17). ($8.00)

Map 83-01 Geological Map of the Hantsport Area, Nova Scotia, compilation and geology by S. A. Ferguson, scale 1:25 000. ($5.00)

Map 83-02 Calculated Vertical Magnetic Gradient Map of the Cape Breton Highlands, Inverness, and Victoria Counties, Nova Scotia, scale 1:125 000. ($5.00)

Map 83-03 Salt and Potash Resources of Nova Scotia, by R. C. Boehner, scale 1:500 000 (accompanies Bulletin 5). ($4.00)

Map 83-04 Geological Map of the Red River Anorthosite Complex, Inverness and Victoria Counties, Nova Scotia, by P. K. Smith and A. S. Macdonald, scale 1:125 000. ($1.50)

Map 84-01 Geological Map of the Cochrane Hill Open-Pit Gold Deposit, Guysborough County, Nova Scotia, by P. K. Smith, scale 1:66.7. ($8.00)

Map 84-02 Geological Map of the Boisdale Peninsula, Central Cape Breton Island, Cape Breton County, Nova Scotia, by Sandra M. Barr and Jeremy R. D. Setter, 1984, scale 1:100 000. ($4.00)

Map 85-01 Industrial Mineral Commodities Map of the Province of Nova Scotia, by John H. Fowler (compiler), 1985, scale 1:500 000. ($5.00)

Map 85-02 Loch Lomond Basin and Glengarry Half Graben, by R. C. Boehner and G. Prime, scale 1:50 000. ($5.00)

Map 85-03 Aggregate Resources, Cape Breton Island, by W. J. Wright, scale 1:125 000(locates and names aggregate pits and quarries). ($3.00)

Map 85-04, 85-05, 85-06 Aggregate Resources, Cape Breton Island, by W. J. Wright, scale 1:125 000 (locates and shows the type, quality and observed thickness of sand and gravel deposits). ($3.00 EACH)

NOTE: Maps 85-3 to 85-6 may be purchased individually or as a set for **$10.00**.

Map 86-01 Geological Map of the Sydney Basin, Cape Breton Island, Nova Scotia; by R. C. Boehner and P. S. Giles, 1986, scale 1:50 000. ($5.00)

Map 86-02 Geological Map of the Windsor Area, Nova Scotia, by Reginald G. Moore and Stewart A. Ferguson, 1986, scale 1:25 000. ($5.00)

Map 87-01 Glacial Geology Map of Mount Uniacke (11D/13 West), by P. W. Finck and R. M. Graves, 1987, scale 1:500 000. ($6.00)

Map 87-02 Glacial Geology Map of Halifax and Sambro (11D/12 and 11D/05), by P. W. Finck and R. M. Graves, 1987, scale 1:50 000. ($6.00)

Map 87-03 Till Clast and Simplified Glacial Geology Map of Mount Uniacke (11D/13 West), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. ($6.00)

Map 87-04 Till Clast and Simplified Glacial Geology Map of Halifax-Sambro (11D/12 and 11D/05), by R. M. Graves and P. W. Finck, 1987, scale 1:50 000. ($6.00)

Map 87-06 Bedrock Geological Map of Halifax and Sambro (11D/12 and 11D/05), by M. A. MacDonald and R. J. Horne, 1987, scale 1:50 000. ($6.00)

Map 87-07 Bedrock Geological Map of Windsor (21A/16 East), by L. J. Ham and R. J. Horne, 1987, scale 1:50 000. ($6.00)

Map 87-08 Bedrock Geological Map of Mount Uniacke (11D/13 West), by M. C. Corey, 1987, scale 1:50 000. ($6.00)

Map 88-13, 88-14 Surficial Geology of Parts of Colchester, Cumberland, Pictou and Hants Counties, Nova Scotia (Sheets 10 and 11), by R. R. Stea and P. W. Finck, 1988, scale 1:100 000. ($8.00 SET)

Map 89-01 The Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 1, (Southwestern Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin 6). ($3.00)

Map 89-02 The Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 2, (Central Nova Scotia), 1986, scale 1:250 000 (accompanies Bulletin 6). ($3.00)

Map 89-03 The Peatland Areas of Nova Scotia, by A. R. Anderson and W. A. Broughm, Sheet 3, (Cape Breton Island), 1986, scale 1:250 000 (accompanies Bulletin 6). ($3.00)

Map 90-01 Geology of the Canadian Salt Company Limited, Pugwash Mine (11E/13A), 630 level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. ($5.00)

Map 90-02 Geology of the Canadian Salt Company Limited, Pugwash Mine (11E/13A), 730 level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. ($5.00)

Map 90-03 Geology of the Canadian Salt Company Limited, Pugwash Mine (11E/13A), 830 level, Pugwash, Nova Scotia, by D. C. Carter, 1990, scale 1:1600. ($5.00)

Map 90-04 Till Clast and Glacial Geology of Chester (21A/09), Nova Scotia, by R. M. Graves and P. W. Finck, 1990, scale 1:50 000. ($11.00)

Map 90-06 Surficial Geology of Parts of Halifax, Pictou, Antigonish and Guysborough Counties (Sheet 12) Map Sheets 11E/09, 10, 15, 16 and parts of 11E/07 and 11E/08, by R. R. Stea and R. A. Myers, 1990, scale 1:100 000. ($13.00)

Map 90-09 Geological Map of Chester (21A/09), Nova Scotia, by M. C. Corey, scale 1:50 000. ($7.00)

Map 90-10 Geological Map of Windsor (21A/16, West Half and part of 21H/01), Nova Scotia, by L. J. Ham, scale 1:50 000. ($6.00)

Map 90-11 Cumberland Basin Geology Map,

Apple River and Cape Chignecto, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. ($6.00)

Map 90-12 Cumberland Basin Geology Map, Amherst, Springhill and Parrsboro, Cumberland County, by R. J. Ryan, R. C. Boehner, A. Deal and J. H. Calder, 1990, scale 1:50 000. ($6.00)

Map 90-13 Cumberland Basin Geology Map, Oxford and Pugwash, Cumberland County, by R. J. Ryan, R. C. Boehner and A. Deal, 1990, scale 1:50 000. ($6.00)

Map 90-14 Cumberland Basin Geology Map, Tatamagouche and Malagash, Cumberland, Colchester and Pictou Counties by R. J. Ryan and R. C. Boehner, 1990, scale 1:50 000. ($6.00)

OTHER MAPS

Geological Map of Nova Scotia, by J. D. Keppie, scale 1:500 000, 1979, with Metamorphic and Structural Map Inserts, by J. D. Keppie and G. K. Muecke, scale 1:1 000 000. ($2.50)

Geological Map of Nova Scotia, Metallic Mineral Occurrence Edition, by J. D. Keppie, D. J. Gregory, A. K. Chatterjee and N. A. Lyttle, scale 1:500 000, 1979, with Structural and Metamorphic Map Inserts by J. D. Keppie and G. K. Muecke, scale 1:1 000 000. ($2.50)

Geological Map of Nova Scotia, Bouger Gravity Anomaly Edition, by J. D. Keppie, scale 1:500 000, 1979, with Metamorphic and Structural Map Inserts by J. D. Keppie and G. K. Muecke, scale 1:1 000 000. ($2.50)

Tectonic Map of Nova Scotia, by J. D. Keppie, scale 1:500 000, 1982. ($5.00)

Metallogenic Map of Nova Scotia, by A. K. Chatterjee, scale 1:500 000, 1983. ($5.00)

Folio of Geological Maps of Nova Scotia - includes Geological, Structural, Metamorphic, Classes of Mineral Deposits, Bouguer Gravity Anomaly and Magnetic Maps, by J. D. Keppie, G. K. Muecke, A. K. Chatterjee and others, scale 1:2 000 000, 1979. ($1.00)

Geological Highway Map of Nova Scotia, Second Edition, by Howard V. Donohoe, Jr., and R. G. Grantham, scale 1:640 000, 1989. (Atlantic Geoscience Society, Special Publication Number 1). ($3.95)

A Map Book of the Province of Nova Scotia, **Geological Edition**, scale 1:250 000, 1979, 46 pages. ($12.00)

Claim reference maps (compilation) of Nova Scotia, scale 1:500 000 (1 white print). ($5.00)

Claim reference maps, scale 1:31680 (white print). ($1.00)

Reservation Grid System for Petroleum Licences, Onshore and Offshore, scale 1:500 000 (1 white print). ($2.00)

MEMOIRS

Comprehensive terminal reports on the geology of specific areas.

Memoir 04 The Older Paleozoic of Pictou County, Nova Scotia, by R. H. Maehl, 1961, 109 pages, 1 appendix, 1 map. ($3.00)

Memoir 05 Pleistocene Geology of the Annapolis Valley, Nova Scotia, by C. F. Hickox, 1962, 36 pages, 1 map. ($2.00)

Memoir 07 The Geology of the George River Series, Cape Breton, by G. C. Milligan, 1970, 111 pages, 7 maps. ($4.50)

MISCELLANEOUS PUBLICATIONS

Documents published by Nova Scotia Department of Mines and Energy without a series title.

MP 58-02 Possibilities for Occurrence of Petroleum Reservoirs in Nova Scotia, by W. A. Bell, 1958, 177 pages. ($1.00)

NOTE: Drilling Logs prior to 1958 are in NSDME Annual Reports.

MP 59-01 Drilling Logs of Government Core Drills, 1958, by M. G. Goudge and D. M. MacLeod, 34 pages. ($1.00)

MP 60-01 Drilling Logs of Government Core Drills, 1959, by M. G. Goudge and D. M. MacLeod, 38 pages. ($1.00)

MP 61-01 Drilling Logs of Government Core Drills, 1960, by C. F. Townsend and D. M. MacLeod, 33 pages. ($1.00)

MP 62-01 Drilling Logs of Government Core Drills, 1961, by C. F. Townsend and D. M. MacLeod, 49 pages. ($1.00)

MP 63-01 Drilling Logs of Government Core Drills, 1962, by C. F. Townsend and D. M. MacLeod, 35 pages. ($1.00)

MP 64-01 Drilling Logs of Government Core Drills, 1963, by C. F. Townsend and D. W. Grimm, 36 pages. ($1.00)

MP 65-01 Drilling Logs of Government Core Drills, 1964, by C. F. Townsend and D. W. Grimm, 43 pages. ($1.00)

MP 66-01 Drilling Logs of Government Core Drills, 1965, by C. F. Townsend and D. W. Grimm, 55 pages. ($1.00)

MP 66-03 Metallic Mineral Occurrences Recorded in the Province of Nova Scotia, by Nova Scotia Department of Mines, 1966, 350 pages. ($4.00)

MP 67-01 Drilling Logs of Government Core Drills, 1966, by C. F. Townsend and D. W. Grimm, 27 pages. ($1.00)

MP 68-01 Drilling Logs of Government Core Drills, 1967, by C. F. Townsend and D. W. Grimm, 39 pages. ($1.00)

MP 68-02 Core Drilling in Nova Scotia with Government Drills, 1871-1966, 176 pages. ($2.00)

MP 69-01 Drilling Logs of Government Core Drills, 1968 by C. F. Townsend and D. W. Grimm, 58 pages. ($1.00)

MP 69-02 Handbook for Companies Planning Offshore Drilling, by Nova Scotia Department of Mines, 1969, 23 pages. ($0.50)

MP 70-01 Drilling Logs of Government Core Drills, 1969, by C. F. Townsend and D. W. Grimm, 65 pages. ($1.00)

MP 71-01 Drilling Logs of Government Core Drills, 1970, by C. F. Townsend and D. W. Grimm, 71 pages. ($1.00)

MP 72-01 Drilling Logs of Government Core Drills, 1971, by C. F. Townsend and D. W. Grimm, 81 pages. ($1.00)

MP 72-03 Clay and Sand Deposit at Elmsvale, Halifax County, Nova Scotia, by J. H. Fowler, 1972, 62 pages & drillhole sections. ($2.50)

MP 72-04 Geology of the Middle River and Baddeck Forks Map Areas, Victoria County, Nova Scotia, by B. E. Jones and T. G. N. Covert, 1972, 124 pages and 5 maps. ($5.00)

MP 75-01 Drilling Logs of Government Core Drills, 1972, by I. MacDougall and D. W. Grimm, 85 pages. ($1.00)

MP 75-02 Drilling Logs of Government Core Drills, 1973, by I. MacDougall and D. W. Grimm, 76 pages. ($1.00)

NOTE: Drilling logs after 1973 are published as part of the Report Series; i.e. Drilling Logs for 1974 are in Report 76-1.

MP 75-03 Core Drilling in Nova Scotia with Government Drills, 1967-1971, 49 pages. ($1.00)

MP 75-04 Bibliography of the Geology of Nova Scotia, by D. J. Gregory, 1975, 237 pages. (OUT OF PRINT) (Microfiche only $4.00)

MP 84-01 Nova Scotia Oil and Gas Report 1984. ($2.00)

MP 85-01 Nova Scotia Oil and Gas Report 1985. ($2.00)

MP 87-01 Nova Scotia Oil and Gas Report 1987. ($2.00)

MP 88-02 Industrial Mineral Mining in Nova Scotia: Proud Tradition, Bright Future, 1988. (FREE)

MP 88-03 Nova Scotia Oil and Gas Report 1988. ($2.00)

OPEN FILE ILLUSTRATIONS

OFI 90-001 Stratigraphic Section of the Joggins Area (21H/09), Cumberland Basin, by R. J. Ryan and R. C. Boehner, 1990, scale 1:2400. ($2.00)

OFI 90-002 Stratigraphic Section of the French River - River John Area (11E/11, 11E/14), Cumberland Basin, by R. J. Ryan and R. C. Boehner, 1990, scale 1:1333. ($2.00)

OFI 90-003 Detailed Drillhole Correlation, Oxford Area (11E/12), Cumberland Basin, by R. J. Ryan and R. C. Boehner, 1990, scale 1:1177. ($2.00)

OFI 90-004 Detailed Drillhole Correlation, Tatamagouche Area (11E/14), Cumberland Basin, by R. J. Ryan, 1990, scale 1:1538. ($2.00)

OPEN FILE MAPS

Open File Maps are unpublished maps on the geoscience of Nova Scotia. They can be authored by any individual, agency or organization. Open File Maps do not necessarily originate from within the Nova Scotia Department of Mines and Energy, although many do. Open File Maps are made available for consultation and use in the Libraries of the Halifax and Stellarton Offices of the Department. A select number of these Open File Maps are available for purchase in hard copy, from the Library in the Halifax Office. All Open File Maps may be purchased in paper or microfiche from Precision Microfilming Services, 3770 Kempt Road, Halifax, Nova Scotia B3K 4X8.

OFM 85-001 Thesis Study Locations in Nova Scotia, compiled by D. B. Hopper, D. R. MacDonald and D. A. Wilkinson, 1985, scale 1:500 000. ($3.00)

OFM 86-049 - OFM 86-056 Gold Compilation of the Meguma Terrane in Nova Scotia, by J. McMullin, G. Richardson, T. Goodwin, 8 maps, scale 1:100 000. ($2.00)

(Copies available from Precision Microfilming Services Ltd., 3770 Kempt Road, Halifax, Nova Scotia B3K 4X8, (902) 455-5451).

OFM 87-004 Preliminary Geology Map, New Germany (21A/10), by R. Horne, scale 1:50 000. ($2.00)

OFM 88-001 - OFM 88-012 Mineral Resource Land Use Maps for Halifax County, by D. B. Hopper and C. A. Dobson, 1988, 12 maps, scale 1:50 000. ($24.00)
($2.00 per map)

OFM 88-013 Preliminary Geological Map of Chester (21A/09), by M. C. Corey, scale 1:50 000. ($2.00)

OFM 88-014 Glacial and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. G. Bent, scale 1:50 000. ($2.00)

OFM 88-015 Preliminary Geological map of Windsor (21A/16 West Half and part of 21H/01), by L. J. Ham, scale 1:50 000. ($2.00)

OFM 88-016 Preliminary Geological Map of Gaspereau Lake (21A/15 and part of 21H/02), by M. A. MacDonald and L. J. Ham, scale 1:50 000. ($2.00)

OFM 88-017 - OFM 88-022 Mineral Resource Land Use Maps for Hants County, by D. B. Hopper and H. J. Gillis, 1988, 6 maps, scale 1:50 000. ($12.00 SET)
($2.00 per map)

OFM 88-024 Geological Map of New Minas-Canaan Quadrangle, compiled by Dr. Stewart A. Ferguson 1976-1978, 1985-1987, scale 1:10 000. ($2.00)

OFM 88-031 Till Geochemistry Map, Pictou and Antigonish Counties (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. ($2.00)

OFM 88-032 Till Geochemistry Map, Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses (Sheet 12), by R. G. Turner and R. R. Stea, scale 1:100 000. ($2.00)

OFM 88-033 - OFM 88-038 Mineral Resource Land Use Maps for Cape Breton County, by D. B. Hopper and H. J. Gillis, 1988, 6 maps, scale 1:50 000. ($12.00 SET)
($2.00 per map)

NOTE: OFM 88-39 to 88-043 are available for viewing at the NSDME library or for purchase from Precision Microfilming Services Ltd., 3770 Kempt Road, Halifax, Nova Scotia, B3K 4X8 (455-5451).

OFM 88-039 Preliminary geological maps of the Cumberland Basin, Tatamagouche and Oxford (11E/11 and 11E/12), by R. J. Ryan, R. C. Boehner and A. Deal, 23 maps, scale 1:10 000.

OFM 88-040 Preliminary geological maps of the Cumberland Basin, Pugwash and Malagash (11E/13 and 11E/14), by R. J. Ryan, R. C. Boehner and A. Deal, 21 maps, scale 1:10 000.

OFM 88-041 Preliminary geological maps of the Cumberland Basin, Cape Chignecto and Parrsboro (21H/07 and 21H/08), by A. Deal, R. J. Ryan and R. C. Boehner, 13 maps, scale 1:10 000.

OFM 88-042 Preliminary geological maps of the Cumberland Basin, Springhill and Apple River (21H/09 and 21H/10), by R. J. Ryan, A. Deal, J. H. Calder and R. C. Boehner, 24 maps, scale 1:10 000.

OFM 88-043 Preliminary geological maps of the Cumberland Basin, Amherst (21H/16), by R. C. Boehner, R. J. Ryan and A. Deal, 11 maps, scale 1:10 000.

OFM 88-044 - OFM 88-049 Mineral Resource Land Use Maps for Kings County (21A/10, 21A/15, 21A/16, 21H/01, 21H/01, 21H/02, 21H/08), by D. B. Hopper and H. J. Gillis, 1989, 6 maps, scale 1:50 000. ($12.00 SET)
($2.00 per map)

OFM 88-050 Till Geochemistry of Northern Mainland Nova Scotia, Clay Fraction Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, map sheet 13-88, scale 1:00 000. ($2.00)

OFM 88-051 Till Geochemistry of Northern Mainland Nova Scotia, Heavy Mineral Separate Analyses, Antigonish and Guysborough Counties, by R. G. Turner and R. R. Stea, map sheet 13-88, scale 1:100 000. ($2.00)

OFM 88-052 Preliminary Till Geochemistry and Till Clast Geology of the Windsor Map Sheet (21A/16), South Mountain Batholith Project, by F. J. Boner, P. W. Finck and R. M. Graves, scale 1:50 000. ($2.00)

OFM 89-001 Geological Map of Kentville-South Alton Quadrangle, compiled by Stewart A. Ferguson, 1987-1988, scale 1:10 000. ($2.00)

OFM 89-002 Geological Map of West Gore Quadrangle, by R. G. Moore, 1988, scale 1:10 000. ($2.00)

OFM 89-003 Geological Map of Newport Corner Quadrangle, by R. G. Moore, 1988, scale 1:10 000. ($2.00)

OFM 89-005 - PFM 89-009 Mineral Resource Land Use Maps for Lunenburg County, by D. B. Hopper and H. J. Gillis, 1989, 5 maps, scale 1:50 000 ($10.00 SET)
($2.00 per map)

OFM 89-010 Preliminary Geological Map of Lake Rossignol (21A/03W), by M. C. Corey and R. J. Horne, scale 1:50 000. ($2.00)

OFM 89-012 Preliminary Geological Map of Weymouth (21A/05), by M. A. MacDonald and L. J. Ham, scale 1:50 000. ($2.00)

OFM 89-014 Preliminary Geological Map of Milford (21A/11), by M. C. Corey and R. J. Horne, scale 1:50 000. ($2.00)

OFM 89-015 Preliminary Geological Map of Digby (21A/12), by L. J. Ham, scale 1:50 000. ($2.00)

OFM 89-016 Preliminary Geological Map of Bridgetown (21A/14), by M. A. MacDonald and L. J. Ham, scale 1:50 000. ($2.00)

OFM 89-017 Geological Map of the Stellarton Basin (West Half), Pictou County, Nova Scotia, by W. D. Smith, K. S. Gillis, S. A. Montgomery, scale 1:5000. ($2.00)

OFM 89-018 Preliminary Glacial Geology of the South Mountain Batholith, Western Nova Scotia, South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, scale 1:250 000. ($2.00)

OFM 89-019 Preliminary Glacial and Till Clast Geology of the New Germany Map Sheet (21A/10), South Mountain Batholith Project, by P. W. Finck, R. M. Graves and F. J. Boner, scale 1:50 000. ($2.00)

OFM 90-002 Glencoe Limestone Deposit, Inverness County, (11F/14), 1988 Diamond Drilling; Diamond Drill Holes and Sections, by R. H. MacDonald, scale 1"=500'. ($2.00)

OFM 90-014 Preliminary Glacial and Till Clast Geology of Gaspereau Lake, 21A/15, South Mountain Batholith Project, by P. W. Finck, R. M. Graves, F. J. Boner and H. B. Bent, 1990, scale 1:50 000. ($2.00)

OFM 90-015 Geochemical Atlas of Nova Scotia: Part I, Drainage Surveys, compiled by P. A. Lombard. ($50.00)

OFM 91-001 Preliminary Geological Map of West-Central Cape Breton Highlands (11K/07 and 11K/10), by R. J. Horne, 1991, scale 1:25 000. ($2.00)

OFM 91-019 Preliminary Geological Map of Kejimkujik (21A/06 and 21A/07), by R. J. Horne and M. C. Corey, 1991, scale 1:50 000. ($2.00)

OPEN FILE REPORTS

Open File Reports are unpublished reports on the geoscience of Nova Scotia. They can be authored by any individual, agency or organization. Open File Reports do not necessarily originate from within the Nova Scotia Department of Mines and Energy, although many do. Open File Reports are made available for consultation and use in the Libraries of the Halifax and Stellarton Offices of the Department. A select number of these Open File Reports are available for purchase in hard copy from the Library in the Halifax Office. All Open File Reports may be purchased in paper or microfiche from Precision Microfilming Services, 3770 Kempt Road, Halifax, Nova Scotia B3K 4X8.

OFR 050 Carboniferous Stratigraphy and Economic Geology, Halifax, Hants and Colchester Counties, Nova Scotia; Canadian Institute of Mining and Metallurgy, Geology Division,

Field Guide, by Mining Society of Nova Scotia and Atlantic Geoscience Society and Nova Scotia Department of Mines, 1974, 48 pages. ($1.00)

OFR 329 The Glencoe Limestone and Dolomite Survey, by D. J. MacNeil, 1977, 252 pages, 12 maps. ($15.00)

OFR 599 Metallic Mineral Occurrences Map and Data Compilation, Central Nova Scotia (Map Sheets 11D and 11E), by M. Ponsford and N. A. Lyttle, 1984, 21 pages, 2 maps. ($3.00)

OFR 600 Metallic Mineral Occurrences Map and Data Compilation, Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11K, 11N), by M. Ponsford and N. A. Lyttle, 1984, 23 pages, 2 maps. ($3.00)

OFR 601 Metallic Mineral Occurrences Map and Data Compilation, Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), by M. Ponsford and N. A. Lyttle, 1984, 21 pages, 2 maps. ($3.00)

OFR 603 Preliminary Feasibility Study for an Underground Gold Mining Operation in Central Nova Scotia, by Nova Scotia Department of Mines and Energy, 1984, 62 pages, 2 maps. ($5.00)

OFR 605 Regional Lake Sediment Survey of the Meguma Zone, Southern Nova Scotia: New Analytical Data, by P. J. Rogers, M. A. MacDonald and D. W. Rigby, 1985, 65 pages, 2 maps. ($5.00)

OFR 606 Industrial Mineral Occurrences Map and Data Compilation, Central Nova Scotia (Map Sheets 11D, 11E), by M. Ponsford, G. DeMont and N. A. Lyttle, 1985, 22 pages, 2 maps. ($4.00)

OFR 607 Industrial Mineral Occurrences Map and Data Compilation, Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11N), by M. Ponsford, G. DeMont and N. A. Lyttle, 1985, 29 pages, 2 maps. ($4.00)

OFR 608 Industrial Mineral Occurrences Map and Data Compilation, Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), by M. Ponsford, G. Demont and N. A. Lyttle, 1985, 21 pages, 2 maps. ($4.00)

OFR 621 Effects of Location on Mine Development Potential: Nova Scotia's Competitive Position in Canada, by D. W. Davis, B. W. MacKenzie and M. L. Bilodeau, 1985, 103 pages. ($15.00)

OFR 648 Current Market Economics of the Strontium Minerals by Metals Economic Group of Halifax, Nova Scotia, and Boulder, Colorado, 1985, 54 pages. ($5.00)

OFR 650 Guide to the Granites and Mineral Deposits of South-western Nova Scotia, edited by A. K. Chatterjee and D. B. Clarke, 1985, 264 pages. ($15.00)

OFR 651 Gypsum Property, Ownership and Leases, by Mark W. G. King, 1985, 140 pages. ($10.00)

OFR 656 The Development Potential for Nova Scotia's Offshore Aggregate and Placer Resources, by John Fowler and Craig Miller, 1985, 69 pages. ($10.00)

NOTE: As of January 1986, all new Open File Reports will have a report number assigned sequentially based upon the year of receipt of the report in the Department.

OFR 86-010 Study of Markets for Aggregate Materials Accessible from Nova Scotia and New Brunswick, by ADI Limited, March 1986, 398 pages. ($10.00)

OFR 86-012 A Study of Industrial Minerals Used

in Oil and Gas Exploration on the Eastern Canadian Offshore, by Jacques, Whitford and Associates, and Cleland, Dunsmuir Consulting Limited, 231 pages. ($17.00)

OFR 86-013 Study of Markets for Silica and Silica Sands Accessible from Nova Scotia and New Brunswick, by ADI Limited, 244 pages. ($10.00)

OFR 86-019 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Central Nova Scotia (Map Sheets 11D, 11E), 280 pages. ($10.00)

OFR 86-020 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Eastern Nova Scotia (Map Sheets 11F, 11G, 11J, 11K, 11N), 355 pages. ($10.00)

OFR 86-021 Compilation of Drillhole Information from Open Assessment Reports Available to the End of December 1985: Western Nova Scotia (Map Sheets 20O, 20P, 21A, 21B, 21H), 235 pages. ($10.00)

OFR 86-025 The Gypsum Industry in Nova Scotia - Present Status and Future Prospects, by R. E. Wright and J. H. Brown; prepared for Nova Scotia Department of Mines and Energy by Center for Resource Studies, Queen's University, 1985, 125 pages. ($15.00)

OFR 86-039 Agricultural Gypsum Project, by Peter Luke, 1986, 9 pages. ($3.00)

OFR 86-054 The U.K. Experience on the Effects of Offshore Sand and Gravel Extraction on Coastal Erosion and the Fishing Industry, by R. Warren Drinnan and Douglas G. Bliss, Dobrocky Sea Tech Limited, August 1986, 90 pages. ($10.00)

OFR 87-002 Market Analysis for New Brunswick, Nova Scotia and Newfoundland Dimension Stone, by the DPA Group Incorporated in association with Jacques Whitford & Associates Limited, March 1987, 66 pages. ($10.00)

OFR 87-005 Report on the Potential Stone Quarry, MacKenzie Farm, Hardwood Hill, Pictou County, Nova Scotia, by G. Dickie, 1986, 37 pages. ($5.00)

OFR 87-023 Report on the English Property (McKeen Quarry), Pictou County, by G. B. Dickie, 1987, 12 pages. ($5.00)

OFR 87-027 Potential Crushed Stone Deposits on Tidewater in Nova Scotia, by G. B. Dickie, 1987, 15 pages. ($5.00)

OFR 87-032 Sulphur in Nova Scotia: Pugwash and Hilden Occurrences, by D. C. Carter, R. C. Boehner and G. C. Adams, 1987, 7 pages. ($5.00)

OFR 88-013 A Study of U. S. East Coast Industrial Mineral Markets for New Brunswick, Newfoundland and Nova Scotia, by Metals Economics Group, 1988. Prepared for Mineral Policy Sector, Energy Mines and Resources Canada, 286 pages. ($15.00)

OFR 88-039 Marine Transport Study for Nova Scotia, by Leslie MacIntyre Maritime Associates Inc., May 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 38 pages. ($5.00)

OFR 88-040 Aggregate Market Study for New Brunswick and Nova Scotia, by ADI Limited, 1988. Prepared for Mineral Policy Sector, Energy, Mines and Resources Canada, 309 pages. ($17.00)

OFR 88-055 Multielement Ratings Maps for Meguma Zone Lake Sediments, by P. J. Rogers, 1989, 34 pages, 3 maps. ($5.00)

OFR 88-056 An Assessment of the Hydrocarbon and Compressed Air Storage Potential of Nova Scotia Salt Deposits, by

Nolan, Davis & Associates Ltd., 1988, 195 pages. ($20.00)

OFR 88-057 Gypsum, Anhydrite Potential, Meadows Road Area, Cape Breton County, by G. Adams, 1988, 29 pages. ($5.00)

OFR 88-059 Interpretation of Till Geochemical Data in Nova Scotia, Canada, Using Mapped Till Units, Multi-Element Anomaly Patterns, and the Relationship of Till Clast Geology to Matrix Geochemistry, by R. G. Turner and R. R. Stea, 1988, 39 pages. ($5.00)

OFR 88-063 An Assessment of the Hydrocarbon and Compressed Air Storage Potential of Nova Scotia: A Summary, by Nolan, Davis & Associates Ltd., 1988, 22 pages. ($3.00)

OFR 89-001 Lithogeochemistry of the Eastern Portion of the South Mountain Batholith, Nova Scotia, (Map Sheets 11D/05, 11D/12, 11D/13, 21A/09, 21A/10, 21A/15, 21A/16, and parts of 21H/01 and 21H/02), by L. J. Ham, S. W. Marsh, M. C. Corey, R. J. Horne and M. A. MacDonald, 62 pages, 2 maps. ($15.00)

OFR 89-003 Open File Report on Selected Mineral Occurrences of the Antigonish Area, (NTS 11E/08, 11E/09 and 11E/16), by K. E. Northcote, G. DeMont and A. Armitage, February 1989, 184 pages plus tables. ($15.00)

OFR 89-004 Open File Report on Selected Mineral Occurrences of Southern Cape Breton Island, Nova Scotia, (NTS 11F/10, 11F/15, 11F/16, 11K/01, 11K/02), by K. E. Northcote, G. DeMont and A. Armitage, March 1989, 94 pages plus tables. ($10.00)

OFR 89-005 Open File Report on Selected Mineral Occurrences of the Cobequid Area, Nova Scotia, (NTS 11E/05, 11E/06, 11E/10, 11E/11, 11E/12, 21H/07, 21H/08), by K. E. Northcote, G. DeMont and A. Armitage, March 1989, 189 pages plus many tables. ($15.00)

OFR 89-006 Summary Report on Quarry Stone Used in the Construction of Dominion Building, Halifax, N. S., by G. B. Dickie, 1989, 16 pages. ($3.00)

OFR 89-007 Geochemical Analyses of Bulk Stream Sediment Samples from Northern Nova Scotia, by R. F. Mills, 1989, includes many tables and 3 sample location maps, scale 1:250 000. ($40.00)

OFR 90-004 Heavy Mineral Till Geochemistry (Tin) of the Eastern and Central South Mountain Batholith, by P. W. Finck, F. J. Boner and R. M. Graves, 1990, 21 pages, 3 maps, scale 1:250 000. ($10.00)

OFR 90-006 Trace Element Analysis of Till (-230 Mesh), South Mountain Batholith, (11D/05, 11D/12, 11D/13, 20P/13, 21A/03, 21A/04, 21A/05, 21A/06, 21A/07, 21A/09, 21A/10, 21A/11, 21A/12, 21A/14, 21A/15, 21A/16, 21H/02), by F. J. Boner, P. W. Finck and R. M. Graves, 1990, 40 pages, 1 map, scale 1:250 000. ($6.00)

OFR 90-007 Lithogeochemistry of the Western Portion of the South Mountain Batholith, Nova Scotia (21A/03, 21A/04, 21A/05, 21A/06, 21A/11, 21A/12, 21A/14), by L. J. Ham, M. C. Corey, R. J. Horne and M. A. MacDonald, 1990, 30 pages and 2 maps, scale 1:150 000 and 1:250 000. ($7.00)

OFR 90-008 Quaternary Geology of Nova Scotia; Guidebook for 53rd Annual Friends of the Pleistocene Field Excursion, May 25-28, 1990, 85 pages, 61 Figures. ($11.00)

OFR 90-009 Investigation of the Chegoggin Point, Lake George, Yarmouth County, (200/16), Silica and Garnet Deposit, by R. H. MacDonald, 1990, 74 pages. ($4.00)

OFR 90-011 Index Map and Map Data Sheets to Published Nova Scotia Department of Mines and Energy Bedrock Geology Maps of Nova Scotia (compiled to August 1990), by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 55 pages plus 1 map, scale 1" to 16 miles (1:1 013 760). ($7.00)
Map only: $2.00.

OFR 90-012 Index Maps and Map Data Sheets to Published Geological Survey of Canada Bedrock Geology Maps of Nova Scotia (excluding Faribault - Fletcher Series), (compiled to August 1990), by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 124 pages plus 2 maps, scale 1" to 16 miles (1:1 013 760). ($17.00)
Maps only: $4.00

OFR 90-013 Index Map and Map Data Sheets to Published Geological Survey of Canada Faribault - Fletcher Bedrock Geology Maps of Nova Scotia, by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 136 pages plus 1 map, scale 1" to 16 miles (1:1 013 760). ($16.00)
Map only: $2.00.

OFR 90-014 Index Map and Map Data Sheets to Published Nova Scotia Department of Mines and Energy and Geological Survey of Canada Surficial Geology Maps of Nova Scotia (compiled to August 1990), by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 34 pages plus 1 map, scale 1" to 16 miles (1:1 013 760). ($5.50)
Map only: $2.00.

OFR 90-015 Index Map and Map Data Sheets to Published Geological Survey of Canada Coloured Total Field and Vertical Gradient Aeromagnetic Maps of Nova Scotia (compiled to August 1990), by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 38 pages plus 1 map, scale 1" to 16 miles (1:1 013 760). ($6.00)
Map only: $2.00.

OFR 90-016 Index Maps and Map Data Sheets to Published Geological Survey of Canada Redline Total Field and Vertical Gradient Aeromagnetic Maps of Nova Scotia (compiled to August 1990), by Patricia L. LeBlanc, Norman A. Lyttle, Janette M. Freeman, 1990, 97 pages plus 2 maps, scale 1" to 16 miles (1:1 013 760). ($14.00)
Maps only: $4.00.

OFR 90-017 Regional Geochemical Surveys Conducted by the Nova Scotia Department of Mines and Energy from 1987 to 1989, by P. J. Rogers and P. A. Lombard, 1991, 53 pages, 23 figures and 3 tables. ($10.00)

OFR 90-019 Summary of the Major Limestone/Dolomite Deposits of Nova Scotia, by R. H. MacDonald, 1990, 15 pages; revised edition of NSDME OFR 86-064. ($3.00)

OFR 90-020 1988 Glencoe Drilling Program, Inverness County, by R. H. MacDonald, 1990, 18 pages. ($4.00)

OFR 90-022 Gypsum in the Murchyville Area (11D/14D), Halifax County, Nova Scotia, by G. C. Adams, 1990, 51 pages, 3 maps. ($10.00)

OFR 90-023 Selected Bibliography of the Geology (Including Economic Geology) of Carboniferous Basins in Nova Scotia, compiled by R. C. Boehner, 1990, 33 pages. ($3.00)

OFR 90-024 A Study of Pits and Quarries Rehabilitation, prepared for Energy, Mines and Resources Canada, Mineral Policy Sector, by Gardner Pinfold Consulting Economists

Limited in association with Robert Parker Associates Limited, Peter Klynstra Landscape Architects Limited, 1990, 100(?) pages. ($10.00)

OFR 91-002 Selected Metallic Mineral Occurrences of Cape Breton Island on NTS map sheets 11F/14, 11K/01, 11K/02, 11K/06, 11K/07, by Garth Demont, 1991, 200(?) pages. ($15.00)

OFR 91-003 Diamond-Drilling of the Big Indian Lake Polyphase Intrusive Suite, Halifax County, Nova Scotia (NTS Map 11D/13), by Michael C. Corey, 1991, 35 pages. ($4.00)

OUTSIDE PUBLICATIONS

Outside publications are documents on the geoscience of Nova Scotia authored by non-Nova Scotia Department of Mines and Energy staff and published externally.

OP-01 Malagash Salt, compiled and edited by John R. MacQuarrie, c.1975, 1981, 109 pages. ($5.00)

Geological Association of Canada/Mineralogical Association of Canada Guidebooks for Field Excursions (Fredericton, May 15-17, 1985).

OP-02 Trip No. 1 Appalachian Geotraverse (Canadian Mainland); J. D. Keppie, K. Currie, J. B. Murphy, *et al.*, 181 pages. ($15.00)

OP-04 Trip No. 10 Igneous and Metamorphic Geology of the Cape Breton Highlands; S. M. Barr, R. A. Jamieson, R. D. Raeside, 48 pages. ($5.00)

OP-05 Trip No. 11 Turbidite-Hosted Gold Deposits, Meguma Domain, Eastern Nova Scotia; P. K. Smith, S. J. Haynes, B. E. Jones, 67 pages. ($7.00)

OP-06 Trip No. 14 Lithostratigraphic, Physical Diagenetic and Economic Aspects of the Pennsylvanian-Permain Transition Sequence of Prince Edward Island and Nova Scotia; H. W. van de Poll, J. R. Degrace, R. J. Ryan. ($7.00)

OP-07 Basins of Eastern Canada and Worldwide Analogues, Programme with Abstracts, Basins of Eastern Canada and Worldwide Analogues Symposium, August 13-15, 1986, Halifax, Nova Scotia, 132 pages. ($8.00)

OP-08 *Atlantic Geoscience Society. Special Publication Number 3.* Occupational Safety in the Geosciences, Programme with Abstracts: A Seminar and Panel Discussion on Safety-Related and Legal Topics Concerning Geoscientists and Their Work Environments, Organized by the Atlantic Geoscience Society, and Co-Sponsored with the Department of Geology, Dalhousie University, The Nova Scotia Chamber of Mineral Resources, the Atlantic Provinces Council on the Sciences, and Geomarine Associates Limited; Dalhousie University, Halifax, Nova Scotia, September 25, 1985, 100 pages. ($2.00)

OP-09 *Atlantic Geoscience Society. Special Publication Number 4.* Carboniferous-Jurassic Sedimentation and Tectonics: Minas, Cumberland and Moncton Basins, Nova Scotia and New Brunswick, by R. C. Boehner, J. H. Calder, D. C. Carter, H. V. Donohoe, Jr., L. Ferguson, R. K. Pickerill, and R. J. Ryan; a Field Trip Guidebook from the Basins of Eastern Canada and Worldwide Analogues Symposium, Halifax, August 1986, 122 pages. ($8.00)

OP-10 *Atlantic Geoscience Society. Special Publication Number 5.* (CSPG Memoir 12). Sedimentary Basins and

Basin-Forming Mechanisms, edited by C. Beaumont and A. J. Tankard; *from* Basins of Eastern Canada and Worldwide Analogues Symposium, Halifax, August 1986, 527 pages. ($70.00)

OP-11 Atlantic Geoscience Society, Colloquium '88, Antigonish, N. S. (Abstracts of Papers). ($4.00)

OP-12 Contributions to the Geology of the Meguma Terrane, Nova Scotia, edited by J. D. Keppie; Special Issue of Maritime Sediments and Atlantic Geology, vol. 22, no. 1, 1986, 135 pages. ($10.00)

OP-13 Quaternary Glaciations, Geomorphology and Sea Level Changes: Bay of Fundy Region, R. R. Stea, Field Trip, July 19 to 30, 1987, for NATO Advanced Study Institutes Programme, International Advanced Course on Late Quaternary Sea Level Correlations and Applications, Halifax, Nova Scotia; 79 pages. ($10.00)

OP-14 The Mining Society of Nova Scotia 1887-1987, by D. Pigot. Published by the Mining Society of Nova Scotia, June 1987, 125 pages. ($10.00)

OP-15 Contributions on the Geology of Granitoid and Host Rocks, Meguma Terrane, Nova Scotia, edited by D. J. Kontak and S. M. Barr; Special Issue of Maritime Sediments and Atlantic Geology, vol. 24, no. 1, 1988, 121 pages. ($10.00)

PAPERS

Discussions of research results, including comprehensive progress reports or detailed geology of a local area. Papers are not specifically economic in focus.

Paper 76-01 Structural Model for the Saddle Reef and Associated Veins in the Meguma Group, Nova Scotia, by J. D. Keppie, 34 pages, 2 maps. ($3.00)

Paper 76-02 Geological Data Collection in the Nova Scotia Department of Mines, by J. D. Keppie and A. K. Chatterjee, 15 pages. ($0.50)

Paper 76-03 Interpretation of P.P.I. Radar Imagery of Nova Scotia, by J. D. Keppie, 31 pages, 1 map. ($1.25)

Paper 76-04 Geology, Geochemistry and Mineral Occurrences of the Northeast Margaree River Drainage Basin in parts of Inverness and Victoria Counties, Cape Breton, Nova Scotia, by B. E. MacNabb, J. H. Fowler and T. G. N. Covert, 30 pages, 12 maps. ($15.00)

Paper 76-05 Guide to the Invertebrate Fauna of the Windsor Group in Atlantic Canada, by R. G. Moore and R. J. Ryan, 57 pages. ($2.25)

Paper 77-01 Tectonics of Southern Nova Scotia, by J. D. Keppie, 34 pages (Reprinted 1980). ($3.00)

Paper 77-03 Plate Tectonic Interpretation of Paleozoic World Maps (with Emphasis on Circum-Atlantic Orogens and Southern Nova Scotia), by J. D. Keppie, 45 pages (Reprinted 1982). ($4.00)
(Microfiche $1.50)

Paper 77-06 Sand and Gravel Resources of Pictou County, by J. H. Fowler and G. B. Dickie, 42 pages, 1 map. ($4.00)

Paper 77-07 Tungsten Mineralization in the Carbonate Rocks of the George River Group, Cape Breton Island, Nova Scotia, by A. K. Chatterjee, 26 pages. ($3.50)

Paper 78-01 Geology of the Ecum Secum Area, Halifax and Guysborough Counties, Nova Scotia, by D. McBride, 12 pages. ($1.00)

Paper 78-02 Age of Igneous Rocks along the Lennox Passage - St. Peter's

Lineament, Southern Cape Breton Island, by J. D. Keppie and P. K. Smith, 10 pages. ($1.00)

Paper 78-03 Geology of the Giant Lake Area, Southeastern Cape Breton Island, Nova Scotia, by P. K. Smith, 30 pages, 1 map. ($2.00)

Paper 78-04 Some Middle Devonian to Lower Carboniferous Rocks of Cape George, Nova Scotia, by J. D. Keppie, P. S. Giles, and R. C. Boehner, 37 pages. ($2.00)

Paper 78-05 Petrology of the Early Silurian Dunn Point and McGillivray Brook Formations, Arisaig, Nova Scotia, by J. D. Keppie, J. Dostal and M. Zentilli, 20 pages. ($1.00)

Paper 79-01 Petrology of the Late Precambrian Fourchu Group in the Louisbourg Area, Cape Breton Island, by J. D. Keppie, J. Dostal and J. B. Murphy, 18 pages. ($1.50)

Paper 79-02 Opencast Coal Reserves at Springhill, by B. Ward, 40 pages, 4 maps. ($4.50)

Paper 79-03 Geology of the Meat Cove Zinc Deposit, Cape Breton Island, by A. K. Chatterjee, 27 pages. ($2.00)

Paper 79-04 Minor and Trace Element Variations in Wisconsinan Tills, Eastern Shore Region, Nova Scotia, by R. R. Stea and J. H. Fowler, 30 pages, 3 maps. ($10.00)

Paper 79-05 Pleistocene Stratigraphy of the Miller Creek Section, Hants County, Nova Scotia, by R. Stea and D. Hemsworth, 16 pages. ($3.00)

Paper 79-06 Effects of Subsidence and Depositional Environment on the Formation of Lithotypes in a Hypautochthonous Coal of the Pictou Coalfield, by J. H. Calder, 23 pages. ($3.00)

Paper 79-07 Carbonate Banks of the Gays River Formation in Central Nova Scotia, by P. S. Giles, R. C. Boehner and R. J. Ryan, 57 pages, 1 map. ($4.00)

Paper 80-01 Geology of the Cape North Area, Northern Cape Breton Island, Nova Scotia, by A. S. Macdonald and P. K. Smith, 60 pages, 2 maps. ($5.00) (Microfiche $2.00)

Paper 81-01 The Fisset Brook Formation at Lowland Cove, Inverness County, Nova Scotia, by P. K. Smith and A. S. Macdonald, 18 pages. ($2.00) (Microfiche $1.00)

Paper 81-02 Major Transgressive-Regressive Cycles in Middle to Late Visean Rocks of Nova Scotia, by P. S. Giles, 27 pages. ($2.00) (Microfiche $1.50)

Paper 81-03 The Windsor Group of the Mahone Bay Area, Nova Scotia, by P. S. Giles, 51 pages, figure in back pocket. ($4.00) (Microfiche $1.50)

Paper 81-04 Principles of Tectonic Mapping Based upon Plate Tectonic Theory, by J. D. Keppie, 11 pages. ($1.50) (Microfiche $1.00)

Paper 82-01 Geology and Geochemistry of Selected Granitoid Plutons of Cape Breton Island, by S. M. Barr, G. A. O'Reilly and A. M. O'Beirne, 176 pages, 44 figures, 13 tables. ($8.00) (Microfiche $2.00)

Paper 82-02 Metasomatic-Hydrothermal Mineral Deposits of the New Ross-Mahone Bay Area, Nova Scotia, by G. A. O'Reilly, E. J. Farley and M. H. Charest, 96 pages. ($5.00) (Microfiche $1.50)

Paper 84-01 Petrology of Granitoid Rocks of the Boisdale Peninsula, Central Cape Breton Island, Nova Scotia, by S. M. Barr and J. R. D. Setter, 1986, 75 pages, includes Nova Scotia

Department of Mines and Energy Map 84-2 folded in back pocket. ($8.00)
(Microfiche $2.00)

Paper 85-02 The Formation of Veins in Greenschist Facies Rocks and the Early Deformation of the Meguma Group, Eastern Nova Scotia, by B. H. O'Brien, 1985, 35 pages. ($3.00)
(Microfiche $1.00)

Paper 86-01 Cretaceous Deposits of Nova Scotia, by G. B. Dickie, 1987, 54 pages. ($15.00)
(Microfiche $3.00)

Paper 89-01 Metallogenic Studies of Southeastern Cape Breton Island, by A. S. Macdonald, 1989, 99 pages, 3 figures in pocket. ($20.00)
(Microfiche $3.00)

Paper 89-02 Geology of the Mabou Highlands, by S. M. Barr and A. S. Macdonald, 1989, 65 pages and 1 geological map in pocket. ($15.00)
(Microfiche $3.00)

Paper 89-03 Re-evaluation of the Coal Resources of Western Cape Breton Island, by P. A. Hacquebard, K. S. Gillis and D. S. Bromley, 1989, 47 pages. ($12.00)
(Microfiche $2.00)

REPORTS

Annual publications including bibliographies, compilations, drill log summaries, indexes, report of activities.

Report 75-01 Report of Activities of the Mineral Resources and Geological Services Division, 1974, by Nova Scotia Department of Mines, 75 pages. ($1.00)

Report 76-01 Drilling Logs of Government Core Drills, 1974, by I. MacDougall and D. W. Grimm, 73 pages. ($1.00)

Report 76-02 Mineral Resources Division, Report of Activities 1975, 145 pages. ($3.00)

Report 76-03 Drilling Logs of Government Core Drills 1975, by I. MacDougall and D. W. Grimm, 47 pages. ($1.00)

Report 77-01 Mineral Resources Division, Report of Activities 1976, 207 pages. ($10.00)

Report 77-02 Superseded by Report 81-4.

Report 77-03 Drilling Logs of Government Core Drills 1976, by I. MacDougall and D. W. Grimm, 33 pages. ($1.00)

Report 78-01 Mineral Resources Division, Report of Activities 1977, 104 pages. ($4.00)

Report 78-02 Drilling Logs of Government Core Drills 1977, by I. MacDougall and D. E. Polley, 72 pages. ($2.00)

Report 78-03 Superseded by Report 81-6.

Report 78-04 Compilation of Isotopic Age Data of Nova Scotia, by J. D. Keppie and P. K. Smith, 54 pages, 7 maps. ($7.00)

Report 79-01 Mineral Resources Division, Report of Activities 1978, 177 pages. ($6.00)

Report 79-02 Drilling Logs of Government Core Drills 1978, by I. MacDougall and D. E. Polley, 54 pages. ($2.00)

Report 80-01 Mineral Resources Division, Report of Activities 1979, 248 pages. ($7.00)

Report 80-02 Index to Drilling Logs of Government Core Drills 1972-78, by N. A. Lyttle and J. Gillespie-Wood, 47 pages. ($3.00)

Report 80-03 Drilling Logs of Government Core Drills 1979, compiled by I. MacDougall and D. E. Polley, 68 pages. ($3.50)
(Microfiche $1.50)

Report 81-01 Mineral Resources Division, Report of Activities 1980, ed. K. A. Mills,

199 pages. ($8.00)
(Microfiche $2.00)

Report 81-02 Compilation of Igneous Chemical Analyses from Nova Scotia, up to 1978, compiled by J. D. Keppie, P. K. Smith and M. A. K. Grice, 114 pages. ($4.00)
(Microfiche $2.00)

Report 81-03 Drilling Logs of Government Core Drills 1980, compiled by I. MacDougall and D. E. Polley, 52 pages. ($3.50)
(Microfiche $1.00)

Report 81-04 Index to Assessment Reports 1864-1980, by N. A. Lyttle and J. Gillespie-Wood, 109 pages. ($10.00)
(Microfiche $3.00)

Report 81-05 Keyword Index to Assessment Reports 1864-1980, by N. A. Lyttle and J. Gillespie-Wood.
(Microfiche only $5.00)

Report 81-06 Index to Publications, Open File Reports and Theses, 1862-1980, by N. A. Lyttle and J. Gillespie-Wood, 222 pages. (10.00)
(Microfiche $3.00)

Report 81-07 Index to Drillhole and Well Data 1862-1980, by N. A. Lyttle and J. Gillespie-Wood, 127 pages. ($10.00)
(Microfiche $3.00)

Report 82-01 Mineral Resources Division, Report of Activities 1981, ed. K. A. Mills, 139 pages. ($7.00)
(Microfiche $2.00)

Report 82-02 Superseded by Report 86-2.

Report 82-03 Keyword Index to Publications in NSDME Report 81-6, by N. A. Lyttle and J. Gillespie-Wood.
(Microfiche only $2.00)

Report 82-04 Keyword Index to Open File Reports in NSDME Report 81-6, by N. A. Lyttle and J. Gillespie-Wood.
(Microfiche only $1.00)

Report 82-05 Keyword Index to GSC Documents on Nova Scotia to 1980.
(Microfiche only $2.00)

Report 82-06 Drilling Logs of Government Core Drills 1981, compiled by I. MacDougall and D. E. Polley, 1982, 60 pages. ($3.50)
(Microfiche $1.50)

Report 82-07 Uranium in Nova Scotia: A Background Summary for the Uranium Inquiry, Nova Scotia, 122 pages, 2 maps (OUT OF PRINT)
(Microfiche only $2.00)

Report 83-01 Mines and Minerals Branch, Report of Activities 1982, ed. K. A. Milla, 404 pages. ($10.00)
(Microfiche $3.50)

Report 83-02 Superseded by Report 86-2.

Report 83-03 Drilling Logs of Government Core Drills 1982, compiled by I. MacDougall and D. E. Polley, 1983, 38 pages. ($3.50)
(Microfiche $2.00)

Report 84-01 Mines and Minerals Branch, Report of Activities 1983, eds. J. Szostak and K. A. Mills, 352 pages. ($10.00)
(Microfiche $4.00)

Report 84-02 Superseded by Report 86-2.

Report 84-03 Superseded by Report 86-4.

Report 84-04 Keyword Index to Theses in Report 81-6, Index to Publications, Open File Reports and Theses 1862-1980, by D. B. Hopper, J. Gillespie-Wood and N. A. Lyttle.
(Microfiche only $5.00)

Report 84-05 Drilling Logs of Government Core Drills 1983, compiled by I. MacDougall and D. E. Polley, 1983, 38 pages. ($3.50)
(Microfiche $2.00)

Report 84-06 Bibliography of the Surficial Geology of Nova Scotia and the Offshore

(with Radiocarbon Date List), by R. R. Stea and V. J. Brisco, 128 pages. ($6.00)
(Microfiche $2.00)

Report 85-01 Mines and Minerals Branch, Report of Activities 1984, eds. K. A. Mills and J. L. Bates, 232 pages. ($10.00)
(Microfiche $3.00)

Report 85-02 Superseded by Report 86-2.

Report 85-03 Superseded by Report 86-4.

Report 85-04 Drilling Logs of Government Core Drills 1984, compiled by I. MacDougall and D. E. Polley, 1984, 32 pages. ($3.50)
(Microfiche $2.00)

Report 86-01 Mines and Minerals Branch, Report of Activities 1985, ed. J. L. Bates, 374 pages. ($12.00)
(Microfiche $3.50)

Report 86-02 Index to Assessment Reports 1981-1985 (with Keyword and Map Indexes), by Norman A. Lyttle, Janet Gillespie-Wood, Gary M. Frotten and Mary Jean Fraser-MacKinnon, 178 pages. ($20.00)
(Microfiche $8.00)

Report 86-03 Drilling Logs of Government Core Drills 1985, compiled by I. MacDougall and D. E. Polley, 1986, 21 pages. ($3.50)
(Microfiche $2.00)

Report 86-04 Index to Publications, Open File Reports, Open File Maps and Theses 1981-1985 (with Keyword and Map Indexes), by N. A. Lyttle, J. Gillespie-Wood, D. R. MacDonald and D. B. Hopper, 647 pages. ($25.00)
(Microfiche $10.00)

Report 87-01 Mines and Minerals Branch, Report of Activities 1986, eds. J. L. Bates and D. R. MacDonald, 270 pages. ($15.00)
(Microfiche $3.00)

Report 87-02 Gold in Nova Scotia: A Bibliography of the Geology, and Exploration and Mining Histories from 1832 to 1986, by Janet Gillespie-Wood, 1986, 500 pages. ($25.00)
(Microfiche $3.00)

Report 87-03 Index to Assessment Reports, Publications, Open File Reports and Open File Maps for 1986 (with Keyword and Map Indexes), by N. A. Lyttle and J. Gillespie-Wood, 1987, 277 pages. ($20.00)
(Microfiche $4.00)

Report 87-04 Drilling Logs of Government Core Drills 1986, compiled by C. Kavanaugh, 1987, 64 pages. ($5.00)
(Microfiche $2.00)

Report 87-05 Mines and Minerals Branch, Report of Activities 1987, Part A, eds. J. L. Bates and D. R. MacDonald, 180 pages.
NOTE: Report of Activities, Part A supersedes Program and Summaries of the Information Series. ($7.00)

Report 88-01 Mines and Minerals Branch, Report of Activities 1987, Part B, eds. D. R. MacDonald and Y. Brown, 292 pages. ($20.00)
(Microfiche $4.00)

Report 88-02 Index to Assessment Reports, Publications, Open File Reports and Open File Maps for 1987, by Norman A. Lyttle, Janet Gillespie-Wood and Kirsten Lindgreen, 1988, 346 pages. ($20.00)
(Microfiche $4.00)

Report 88-03 Mines and Minerals Branch, Report of Activities 1988, Part A, eds. D. R. MacDonald and Y. Brown, 250 pages. ($7.00)
(Microfiche $3.00)

Report 89-01 Mines and Minerals Branch, Report of Activities 1988, Part B, eds. Y. Brown and D. R. MacDonald, 1988, 133 pages. ($9.00)
(Microfiche $2.00)

Report 89-02 Index to Assessment Reports, Open File Maps, Open File Reports and Publicaions for 1988, by Norman A. Lyttle, Janet Gillespie and Janette Freeman, 1989, 88 pages. ($10.00)
(Microfiche $2.00)

Keyword Index to Report 89-02.
(Microfiche $2.00)

Report 89-03 Mines and Minerals Branch, Report of Activities 1989, Part A, eds. D. R. MacDonald and K. A. Mills, 175 pages. ($7.00)
(Microfiche $3.00)

Report 90-01 Mines and Mineral Branch, Report of Activities 1989, Part B, eds. D. R. MacDonald, 1990, 112 pages. ($7.00)
(Microfiche $2.00)

Report 90-02 Index to Assessment Reports, Open File Maps, Open File Reports and Publications for 1989, by Norman A. Lyttle and Janette M. Freeman, 1990, 70 pages. ($7.00)
(Microfiche $2.00)

Report 90-03 Program and Summaries, Fourteenth Annual Open House and Review of Activities, ed. D. R. MacDonald, 1990, 54 pages. ($4.00)
(Microfiche $2.00)

SAMPLE CATALOGUES

SC 89-01 Nova Scotia Dimension Stone for Designers, Developers and Quarriers, 1989. (Comprehensive catalogue of 11 Nova Scotia building stones; includes actual sample tiles plus Information Series No. 19). ($100.00)